F. Rabiza

Space
Adventures
in your
Home

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Space

in your

Adventures Home

TO THE YOUNG READER. Dear youngsters! To be sure, most of you dream of visiting space or even of becoming an astronaut, taking part in the conquest of space or travelling to other planets. But we should not forget that the road into space is not an easy one. Space is not only the romantic and exciting adventures described in science fiction, but also painstaking work full of risk and hardship. And those of you who want to devote your lives to space should remember this.

Where does the road to space begin? Above all, with hard work. Would-be astronauts have to be educated people and good sportsmen; healthy, strong, and tough.

Of course, you read books on space, and this book is also concerned with space. But this is not just a good reading, nor is it just a textbook. It is meant to be read as a make-it book and think-it book. You will make simple models and devices to perform fascinating "space" experiments.

Who knows, maybe these simple projects will eventually lead you to the ramp of a spaceship.

Good luck, dear friends, and a happy journey!

V. Lazarev
Soviet cosmonaut,
Hero of the Soviet Union

AUTHOR'S PREFACE. We live in an era of space exploration. The first man to pave the road to space was Yuri Gagarin. His flight on the *Vostok* spacecraft on April 12, 1961, went down in history as an outstanding event.

But before Gagarin's flight the world marvelled at the first artificial satellite launched in the Soviet Union. Now the many satellites orbit the Earth, interplanetary automatic stations visit not only the Moon, but also Mars and Venus. And the *Venera* missions. Aren't they amazing. These automatic vehicles have sent considerable data to the Earth from the surface of this mysterious planet, Venus, and the first TV pictures!

And what an enormous amount of work is performed by astronauts during space missions on ships and long-term orbital stations!

But the conquering of outer space has only just begun. Much work has yet to be done. And boys or girls who want to devote themselves to space must prepare for it now.

Astronauts, spacecraft designers, and scientists involved in space programmes are people of formidable education and knowledge. To become one of them requires much study, research, and experimenting. *Space Adventures in Your Home* will help you perform experiments on your own. Of course, this book (the idea is due to the writer V.D. Pekelis) deals not with the outer space, it is concerned with projects involving phenomena relating to space. You can carry them out at home or at a school engineering club. The experiments described are based on the physical laws studied at school. You will find experiments on atmospheric pressure and vacuum, heat, inertia, and weightlessness. You will also enjoy simple trials in spectral analysis, will become acquainted with the principles underlying the remote control of model PRV's (planetary roving vehicles), with the landing by parachute on Earth of a "descending capsule", and its soft landing. You will even be able to carry out a "space manoeuvre" – to dock two box kites in the air.

This book will help you test your knowledge in practice and take the first steps towards invention. The recommended models are not accompanied by drawings, since the author wants you to show your enterprise and use any bits and pieces available. To store the materials required to make the exciting things in this book and to perform experiments, find a case with boxes or partitions to contain suitable tools and supplies: bolts, screws, nuts, washers, tubes, wire, empty spools, metal balls, parts of toys, etc., etc.

A word about workmanship. Do not make a mess everywhere: do not misplace tools, and tidy up the place after you have finished. Never use household things if they can be damaged. If you need an object, ask the owner if you may have it.

Each project in this book has been tested by the author practically, but to be able to perform any of the experiments described here requires perseverance and concentration.

It may well be that in the course of work you will face difficulties – do not hesitate to apply for help and advice to teachers, parents, and friends. You will be mastering wood- and metal-working procedures as you progress through the projects, and then you will be able to share your experience with your mates.

Good luck, friends!

TWO IRRECONCILABLE ENEMIES. Speaking of *outer space* conjures up visions of cold airfree wastes beginning just beyond the Earth's atmosphere, dead space. No air, no life.

On Earth, there is no emptiness under natural conditions. Earthly nature does not tolerate emptiness. Whatever rarefication in the atmosphere it will in no time be filled with the surrounding air.

Experiments with the Atmosphere and Emptiness

And if, for example, volcanic activity dislodges colossal strata of rock to form voids – huge caves – inside the earth, these are rapidly filled with water or petroleum, air or gas, and on occasion, by lava.

Space has no ideal emptiness, either. You can find extremely rarefied gas there, and finest cosmic dust, if only in minute amounts.

People were slow to understand that air has weight. It had long been considered weightless. On the Earth's surface the weight of the air is appreciable, and air exerts a force of around one kilogramme per each square centimetre of the Earth's surface. This pressure is called *atmospheric pressure*. We bear it easily and do not even notice it, because the pressure inside us compensates for the external pressure. A vacuum does not occur naturally, but beyond the Earth and its atmosphere, in space, vacuum is powerful and insidious. The tiny atmosphere inside a space vehicle must be painstakingly protected from it by hermetic seal. All the hatches must be tightly closed. A slightest leak or smallest slip may lead to the shipboard air disappearing to insatiable space.

You know that to leave the craft to walk in space an astronaut puts on a space suit and a portable life support system (PLSS) to supply breathing air. At first the astronaut goes through a hatch to an airlock, and the hatch is closed thoroughly. Next another, outer, hatch is opened, and the small amount of air in the airlock rushes out into empty space. The astronaut comes out.

This poses a question: How is air retained near the Earth? Why does not it diffuse into the endless reaches of space?

Our thanks should go to gravity. Terrestrial attraction holds fast onto Earth not only people, and everything else but also the air. The closer to the Earth's surface, the denser the atmosphere. But at an altitude of one hundred kilometres it is extremely thin, so that this altitude is considered to be the boundary of space.

Planets that are smaller than the Earth have a smaller attraction, therefore their atmosphere, if any, is exceedingly thin.

Despite its "vile temper", vacuum, is sometimes quite useful and necessary. There are industries where a vacuum is indispensible and must be created artificially. Admittedly, a complete vacuum, even a space vacuum, is impossible to achieve, but still air pumps are able to provide a fairly high evacuation, that is quite sufficient for a variety of technical purposes. And these purposes are really variegated. Vacuum is used in metallurgy to obtain high-quality metals, in the faundry and many other industries. Electronic and TV tubes cannot operate unless air is removed from them.

Space vacuum, too, may be of some use. Space vehicles travel in empty space easily, suffering no drag. Also, astronomers of Earth dream of observatories beyond the terrestrial atmosphere, without any air to hinder the observation of celestial bodies. Even now some astronomical observations are being successfully carried out from orbital stations.

VACUUM IN YOUR HOME. You are sure to have devices at home with a locked, or "canned", vacuum.

Radio and TV receivers use many evacuated electronic tubes. Electrons leaving the hot cathode must get to the anode unhindered. But this is only possible with a high rarefaction of the air. The same is true of the television tube: electrons must hit the screen of the tube and draw the image that we see. For this purpose, electrons must travel inside the tube without hindrance. The screen is convex, and with good reason. The convex surface easily

bears the atmospheric pressure, which is quite appreciable. If the
surface area of the screen is 730 square centimetres, then the force
exerted by air on the glass is about 730 kilogrammes, just under
three quarters of a tonne. The convex surface is able to withstand
this load.

Arches are normally made with curved vaults, because building
materials resist compression better than extension. Not only build-
ing materials, however. Consider the chicken egg. A hen never de-
stroys a single egg in hatching, but a weak chick easily breaks the
egg from within when the time is ripe for it to get out. You may
prove for yourself that an egg shell is much easier to break from
the inside than from the outside. Just tap the shell with a rather
blunt pencil first from the outside, then from the inside.

In your household you may find one more device incorporating
a vacuum, a thermos.

In scientific laboratories are widely employed Dewar vessels for
storage of liquid air and other liquid gases. Liquid gases have

Emptiness

Emptiness

Emptiness
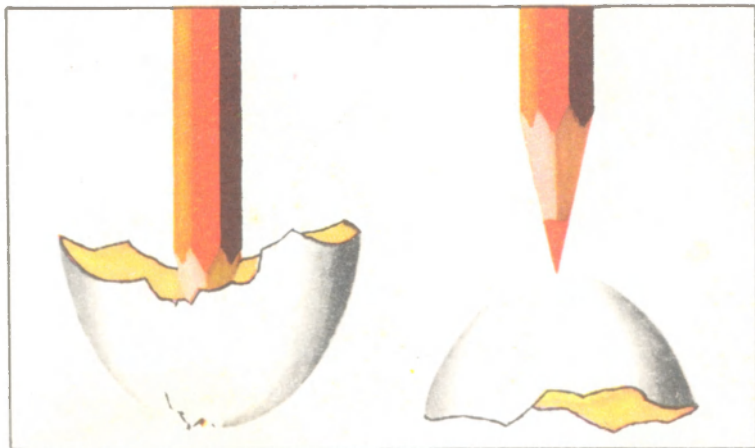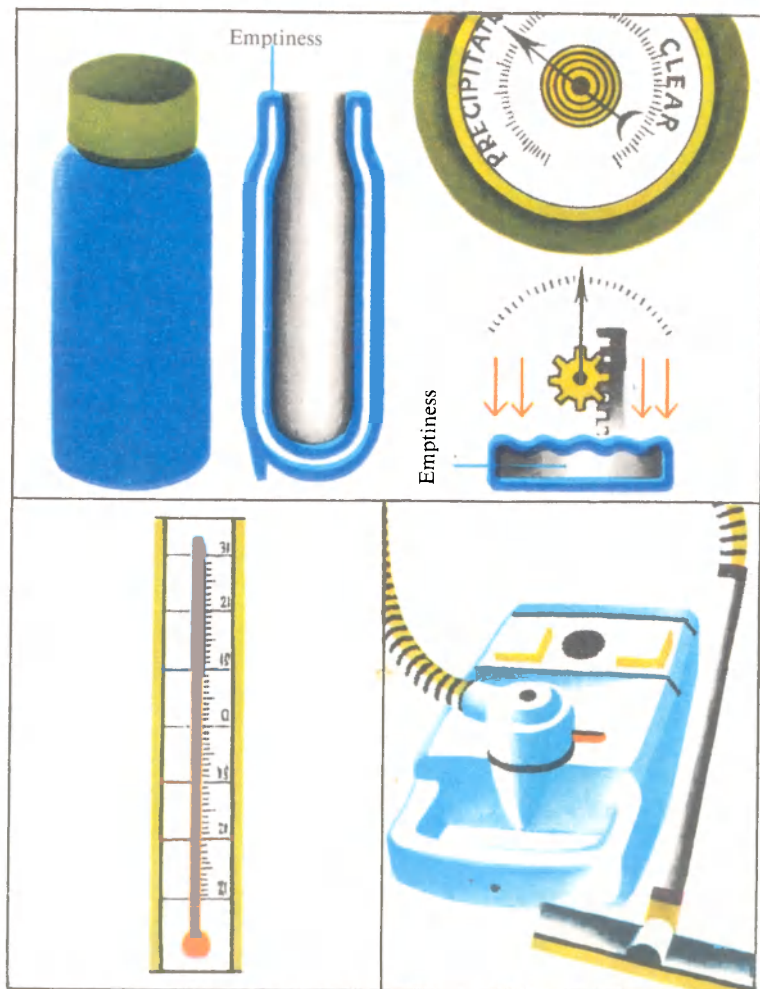
extremely low temperature and, were it not for this special vessel, they would evaporate straight away and turn back into gases.

The Dewar has double walls that are silver-plated on the inside and the space between the walls is evacuated. Owing to this empty space, heat is not transferred from the inner wall to the outer one and vice versa. The silver is also there with good reason: thermal rays will be reflected without heating the glass. Such a vessel protects the cold from heating and the hot from cooling. Therefore in a thermos, being essentially a Dewar vessel, you can store hot tea and coffee for a long time.

In Meteorological Centres you can find mercury barometers to measure atmospheric pressure. But barometers, known as aneroids, also come in metal casings. One of these is simply an evacuated metal box with a corrugated, springlike, cover and a device to connect the cover with a pointer. The scale is graduated in millimetres of mercury (mm Hg). All the fluctuations of atmospheric pressure associated with weather changes are felt by the cover. It either depresses or returns to normal, and the pointer indicates the atmospheric pressure at the moment.

There may not happen to be a barometer in your home, but you are sure to have a thermometer. The thermometer has a thin internal channel for mercury or tinted alcohol to rise and descend. There is no air in the channel, otherwise it would block the motion of the liquid that fills the bulb of the device.

On heating, the mercury or alcohol in the bulb expands and the column of liquid rises. On cooling it descends.

Nowadays vacuum cleaners are widely used for cleaning premises. Its powerful fan produces strong rarefaction and sucks the air in together with dust wherever it may be.

EQUIPMENT FOR EXPERIMENTS. Before we set out to perform our experiments on atmospheric pressure and vacuum (true, we will never achieve a real vacuum under domestic conditions, therefore we ought to refer to it more modestly as rarefied space),
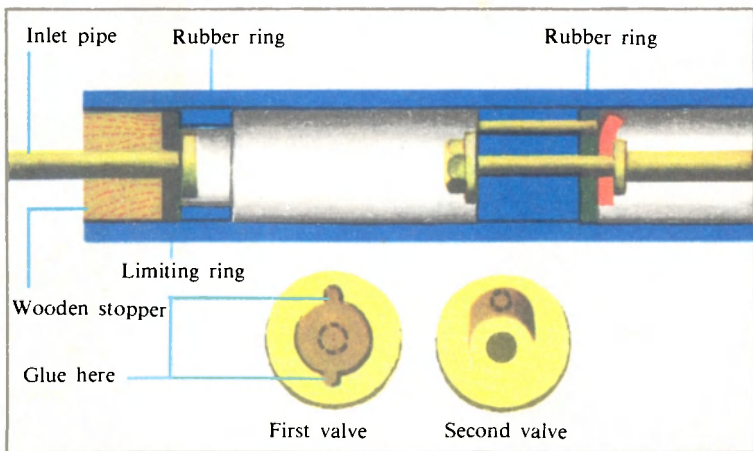
we must provide ourselves with some devices and equipment.

For our experiments we will require a thin-walled glass tumbler, a glass plate (e.g., an old 9×12 cm negative, or just a sheet of glass to cover the tumbler), several glass jars of various sizes, a small phial, two rubber tubes (one thick and the other thin), a deflated baloon, and an air pump. The pump we will make.

You will see as we go along what else will be needed for the experiments. For instance, a polyethylene (plastic) cover, strings, Plasticine, corks, plastic straws, and the like.

You should find all these things fairly easily, but the manufacture of the pump is a more complex task. To make a good pump requires a great deal of effort. But a good pump will allow many an exciting experiment to be performed.

Thus, we begin by making the pump. The principle of the pump is exceedingly simple. The air pump was invented in the 17th century by Otto von Guericke, the bürgomeister of Magdeburg. He used an impressive experiment to demonstrate the tremendous

Inlet pipe   Rubber ring   Rubber ring

Limiting ring

Wooden stopper

Glue here

First valve   Second valve

power of atmospheric pressure. A sphere formed of two copper bowls 37 cm in diameter could not be pulled apart by several horses after the air had been removed from the sphere. And when the bowls were finally separated, there was a sound like a shot.

The accompanying figure schematically shows the pump that we shall manufacture. It must have two valves that help the piston remove the air from the reservoir to which the pump is connected by alternately opening and closing.

The size of the pump is determined by materials available.

To begin with, find a brass, copper or steel tube about 3-5 cm in diameter and no more than 0.5 m in length. The inner wall of the tube must be extremely smooth. Into one end of the tube we will insert a piston, and into the other end we will install a stopper with a small inlet pipe onto which a rubber hose will be slid. Before the stopper is secured in place it must have a valve on the inside end. To do this, you cut out to size a rubber disc with a small opening in the centre. Using a rubber glue, fix to it a small flap of thin rubber (e. g., cut out of an inner tube or a ball bladder). If the stopper is screwed on the tube end, then the rubber disc can be simply put to the tube end and pressed by the stopper cap. Alternatively, a wooden plug should be made and a rubber disc with a valve glued to it from the inside. Then the plug is tightly driven into the pump tube. The valve flap is glued to the rubber disc at two opposite places on the edge. When the air pressure inside the chamber builds up, the flap is pressed tightly to the opening and closes it. When the air flows from the opening, it pushes open the flap and passes between the flap and the rubber disc.

The piston is made as follows: cut out of the thick sole of an old boot several discs of a diameter equal to the inner diameter of the tube, stack them to obtain a cylinder 2-2.5 centimetres high. Through the middle of the cylinder punch a hole to receive a rod or a tube 10-15 centimetres longer than the pump tube. It would be a good thing for you to cut a thread at the end of the rod or thin tube and squeeze the piston with a nut between two

washers on the rod. If this is not possible, squeeze the piston between two washers and fasten them either by pins inserted into bores in the rod or by soldering the washers to the rod.

Drill a hole through the piston, parallel to the rod and several millimetres in diameter, and then insert into it a thin copper tube of the same length as the piston. For the copper tube to stay in position its ends should be expanded with a nail. On the piston, glue another rubber disc, as shown. In the disc a hole should be made, such that, when applied to the piston, the hole should coincide with that of the copper tube. Using the rubber glue, attach a flap of thin sheet rubber near the hole so that one edge of the flap could be turned back to expose the hole. Thus our pump is supplied with the second valve. If you have worked accurately, when the valves are closed, no air must pass through them. But they will open themselves, when the air pushes the flaps from behind.

Now, using a file and sand paper, trim the piston so that it be
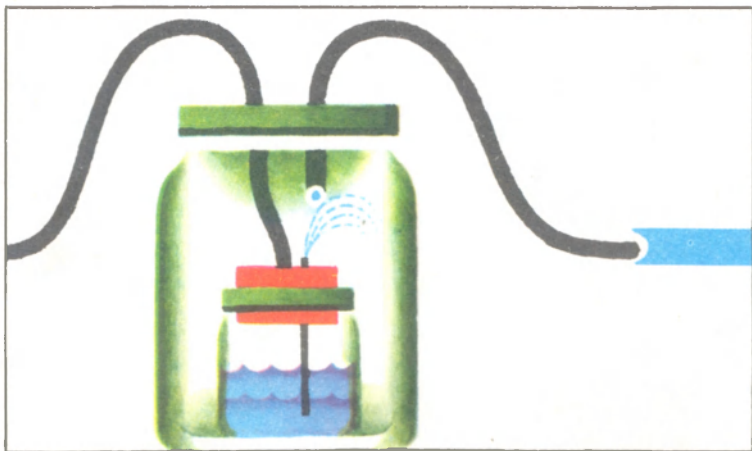
a tight sliding fit in the tube, then slide it into the tube and attach a handle to the outer end of the rod. The tube has a stop attached to its end to prevent the piston from sliding out of the body. Now, slide a rubber hose on the inlet pipe, and the pump is ready. As you slide the piston out, a finger applied to the hose end must adhere, and as it is pushed in, the pump must neither force nor pump out the air.

If you have not yet made an air pump as described (you are going to need it for many experiments), and you have a bicycle pump, then for the following three experiments it can be used after a slight adaptation. To this end, remove the piston, unscrew the nut at the end of the piston rod, take down the rubber piston and reinstall it back to front, and screw the nut home again (see the accompanying figure). Now the pump will not force the air out but suck it in. But it should be used very hard for the air not to leak back into the rarefied space through the piston.

In order to see how the bicycle pump operates in its new capacity, and to see if it creates the desired rarefaction, use a small trick.

Take a funnel (now they are normally made of plastics), attach its narrow end to the pump's hose, and cover the wide end with the envelope of a balloon. Having stretched the film, fasten it tightly. Begin to operate the pump. If the film sucks into the funnel and stays like this, while you continue to use the pump – everything is in order. If the rubber film now sucks in, now straightens when you push the piston in – the pump leaks. This can occur both through the piston and through hose connections.

But if the film bulges in both directions, that is no good at all. In that case the pump both forces and sucks. It should then be dismantled to increase the diameter of the piston rubber or leather by pushing its edges aside. Smear the piston with grease or Vaseline.

FOUNTAIN IN A JAR. We now proceed to do experiments for which your pump will be needed.

Take a small glass phial, fill it with water stained with water colour, and stopper it up tightly. The stopper should be prepared as follows: insert a plastic straw in it through a hole and, through another hole, a thin long rubber tube (e. g., the tube used for bicycle nipples). The straw must reach down to the bottom of the phial, and the rubber tube only to the surface of the water. Fuse the outer (short) end of the straw with a match flame and punch the tip with a pin to give it a tiny hole. Put the phial inside a 3-litre glass jar. Close the jar tightly with a plastic cover, having passed through a small hole the long end of the thin rubber tube. In the cover make one more hole and insert into it a thicker rubber tube. Seal with Plasticine the places around the holes on the cover. The device is ready. Connect the pump to the thick tube and start pumping.

In the jar the air is rarefied, the external atmosphere through the thin tube presses on the water, and a thin coloured jet begins to strike from the straw.
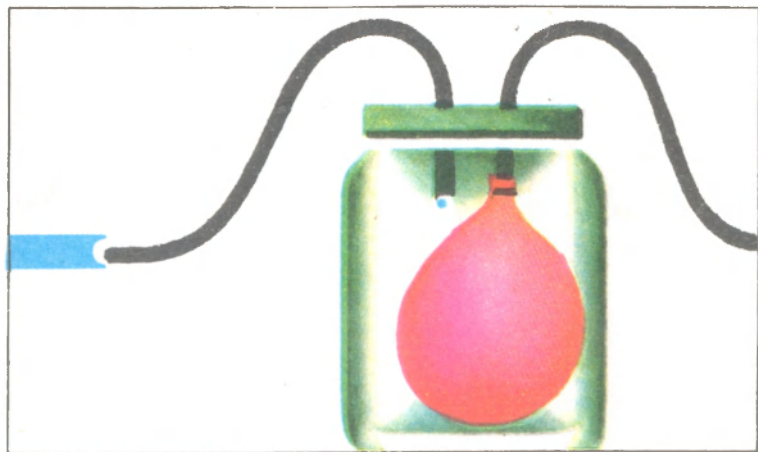
EMPTINESS INFLATES A BALLOON. Now we shall inflate
a balloon in a somewhat unusual way. We shall not blow hard to
fill its envelope with air, as is ordinarily done. Instead we shall
remove air around it, and air from the external atmosphere will
itself enter into the envelope to inflate it.

Take the same jar as in the previous experiment, rinse and wipe
it dry. Remove the phial, and instead attach the envelope to the
thin tube using a thread. Close the jar tightly with the cover and
draw the thin tube out so that the envelope will hang inside just
under the cover. Start pumping hard. As the air leaves the jar, the
balloon will begin to expand and quickly fill all the inside of the
vessel.

You will see that the balloon is inflated, even though you did not
so much as touch it. By the way, the balloon filling the whole in-
side of the jar shows graphically that you have removed just the
same amount of the air.
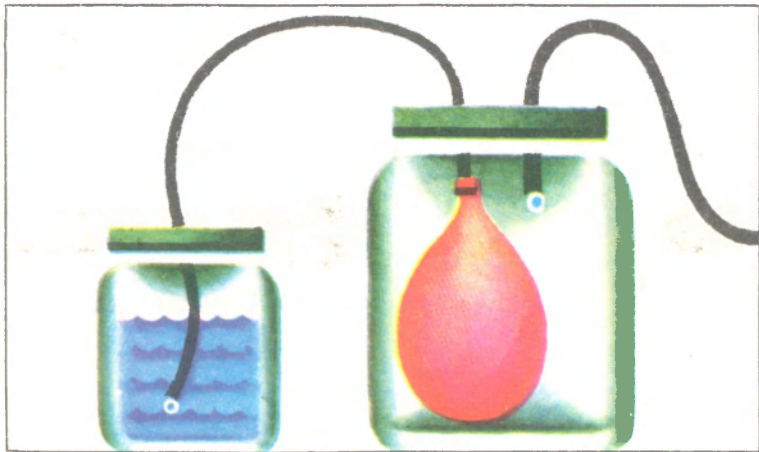
THE BALLOON CHANGES ITS NAME. When the balloon has inflated adequately, dip the outer end of the thin tube into a vessel with water and stop pumping the air out. Clamp the thick rubber tube with your fingers, disconnect the pump and gradually start to let the air into the jar. The air from the balloon will go out bubbling. When it is almost completely out, reattach the pump to the thick tube and start again to pump the air out of the jar. Now the envelope will fill with water. Atmospheric-pressure drives water into it, turning the air balloon into a water balloon. Try to fill the envelope with as much water as possible, and if the envelope does not burst, the volume of the pumped water will correspond to that of the removed air.

VACUUM PUMP FROM A BLOTTING PAPER. You will know well the experiment in which a glass filled with water is covered with a sheet of common paper, the paper is held onto the
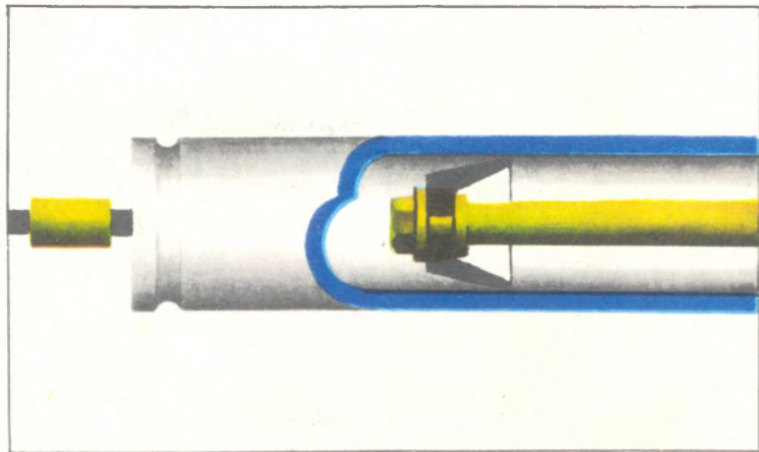
glass, the glass is turned upside down, and the hand is removed, but the water does not pour out. When some adult showed you this experiment, which rather looks like a conjuring trick, he is sure to have explained that it was the atmospheric pressure that did not allow the water out.

This experiment can be improved by additionally rarefying the air in the glass. Fill the glass with water up to the brim, cover it with a blotting paper, or a paper napkin. Put a glass plate on the top and carefully turn the glass upside down. Once the water has been absorbed a bit into the paper, again turn the covered glass over and put it into a pan, just in case. On the bottom of the pan put something soft – a rag or a sponge. Raise the glass plate carefully, and absolutely horizontally. The glass will rise with it. The absorption of water by the paper produced a rarefied space, and the external pressure pressed the plate tightly to the glass. Now the weight of the water is supplemented by the weight of the glass itself. And to detach the plate a certain force is required.
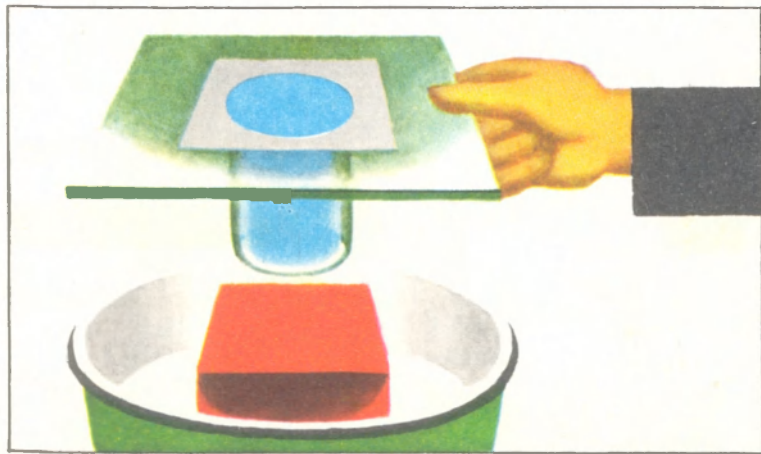
RAREFACTION BY COOLING. If, in the preceding experiment,
the rarefaction in the glass was produced by the water being
removed from hermetically closed glass, we will now perform an
experiment where the rarefaction occurs due to the cooling of the
air.

Take two soup-plates, one with cold water, and the other, with
hot. Put a cork on the surface of the water in each plate. Cover
the cork in the hot water with a glass turned upside down. The air
in the glass will expand and force the water out. So little water will
remain that the cork will not float any more, and will descend and
sit onto the bottom of the plate. Here you have a small model of
a diving bell. A real diving bell, essentially a steel box without
a bottom or a cylinder open at one end, is lowered onto the bed of
a river or other reservoir where some work is to be done. The air
inside is compressed and does not let water in. Workers can
stay inside the bell, the breathing air being under pressure.
More advanced rigs for submerged operations are called caissons.
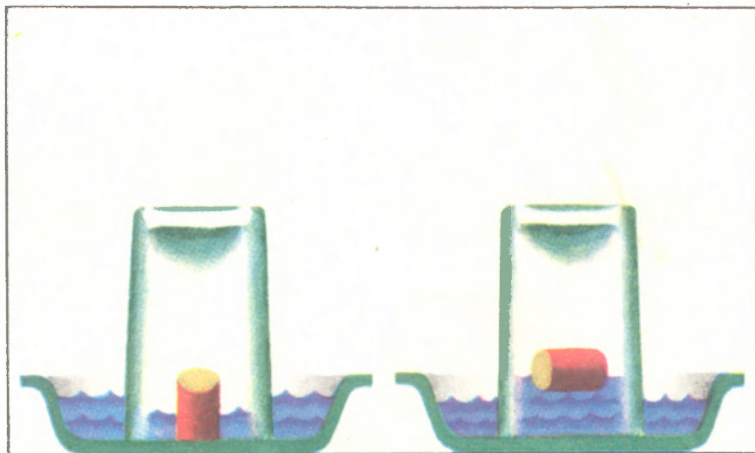
Now take a second glass, warm it adequately first with warm water, then with boiling water, and quickly cover with it the cork that floats in the cold water in the other plate (the warm water here is required for the glass not to break on immersion). At first the cork will descend with the water, and then, as the glass and, of course, the air inside, cools down, the water with the cork will rise. When the glass has fully cooled, its water level will be higher than that of water in the plate.

On cooling the heated air decreased in volume. The pressure inside the glass dropped and the atmospheric pressure drove water into the glass.

AIR DEFEATS IRON. This is a widely known experiment, described in many physics textbooks. But under household conditions the experiment cannot be carried out – a special can is required, and it also will be destroyed just after the first experiment.

The engineer E. I. Orlov, an author of many fascinating physical experiments, suggested a simple and convenient way of conducting this experiment at home.

To be able to perform the experiment you are required to be quick and good at soldering. If you cannot solder yet, ask somebody to help.

Get a can of juice. The can must be large, no less than 0.8 litre. Punch a tiny hole with a nail at the edge of the top. At the opposite edge punch another hole. Now you will be able to empty the can (at first shake the overturned can, then the juice will pour freely). If your can contains not juice, but fruit-salad, then instead of a second small hole in the end face you will need an opening to remove fruit from the can. Next the can must be washed and filled with water to 1/4 of the capacity. The opening must be covered with a tin-plate patch and the edges must be thoroughly soldered with tin.

With the juice can, one of the small holes must be soldered after it has been filled to 1/4 of the capacity.

Put the can with the water on a fire. The water will soon boil, and the steam will escape violently from the remaining hole. Allow the water to boil for several minutes for the air to leave the can and the space above the water to be filled with vapour only.

Soldering things must be at hand and ready. Quickly take down the can from the fire and solder the hole closed. The success of the experiment depends on the quality and speed of the soldering operation.

Put the can under a stream of cold water. Just under your very eyes the can will crush as if squeezed by mighty invisible hands.

What is the matter? As was said, the air from the can had been replaced by steam, the steam under the action of cold water had condensed, i.e., changed into water, and above its surface a vacuum had formed. The can, rather strong for the storage of a small amount of juice, is not meant to have air removed from it and to be subjected to powerful atmospheric pressure.

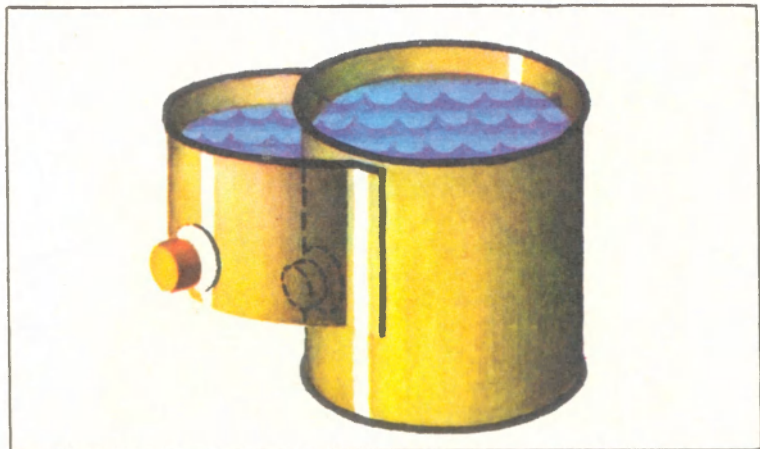If, in the course of the experiment, you hear whistling or hissing
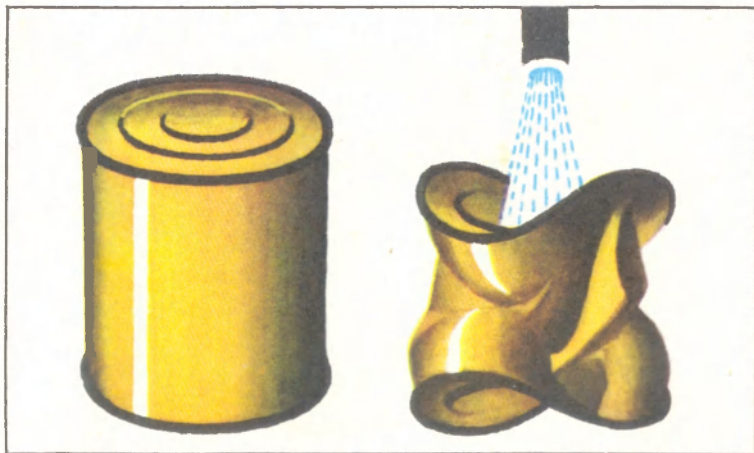
noise, the soldering will be inadequate. Unsolder the just-soldered hole, clean it, put the can on the fire again, and repeat everything as before.

MODEL OF AN AIRLOCK FOR A SPACEWALK. The principle of the airlock for the spacewalk of an astronaut is the same as that of the lock to pass ships around the dam of a hydroelectric power plant or from one river to another. Only the scale here is different, and in one case we deal with air, and in the other with water.

We now make a small model of an operating airlock module in which air will be replaced by water. Our model will in no way claim resemblance to facilities used in space vehicles. The aim of our model is to get acquainted with the principle of the airlock module of a spaceship.

A large open tin can will be our "spaceship". In its side cut a 2-cm dia round hole, and solder a smaller can opposite the open-

ing, as shown in the figure. The smaller can will act as the lock. All the cuts should be very accurate, especially in the bottom, where the circular cut should fit the cylindrical surface of the larger can. In the "lock module" opposite the opening in the side face to which it will be soldered cut a similar opening at the same level. A better connection of the "lock module" with the body of the "ship", the vertical sides of the former having their edges turned back, will be provided to form 5-mm strips. These strips should fit the surface of the larger can tightly. Tie the "lock" with wire to the body of the "ship" and solder all the connections.

Our small cut-away model of the ship is ready. Into the openings, insert from the inside bottle corks trimmed carefully so that these close the openings tightly and do not let water leak.

Now fill the model with water so that the water covers the plugged openings. Carve a wooden figure of an astronaut in a space suit with oxygen bottles strapped to his back, tie a thread to him with the second end fasten within the ship, and place your astronaut on the water. He will float in it as if weightless. Next remove the plug from within, lead the figure on the thread inside the "lock" and plug the opening up (the thread will not prevent this). Then open from within the second, outer opening. The water from the "lock module" will flow out. Let the figure go out into "open space" and replug the opening. The return operation is performed in the reverse order: open the outer opening, introduce into the "lock" the "astronaut" and plug the outer opening. Pour water from a glass into the "lock", thereby creating there "normal atmospheric pressure", and then open the internal opening and let the "astronaut" inside the "ship", plug up the opening.

To be sure, when astronauts really leave the airlock to walk in space, the procedure is much more complicated. But we used water instead of air to present the operation graphically.

In real airlocks, the hermetically sealed hatches are opened or closed by an electric mechanism but facilities are also provided for manual operation.

Man first walked in space on March 18, 1965. It was the Soviet cosmonaut Alexei Leonov who did this. After leaving the airlock of his *Voskhod 2* spacecraft, he "walked" 5 metres away from the hatch and spent 12 minutes exercising on the end of a safety line. His heroic experiment, just like Gagarin's deed, went down in records of the space era and was considered to be a landmark in space history.

AN IDEA PUT INTO PRACTICE. As early as three centuries
ago, Isaac Newton suggested that it would be possible to create an
artificial satellite of the Earth.

He proved that if a "physical body" was launched around the
Earth with a sufficient velocity, and if it travelled in empty space,
then it would never return to the Earth and would orbit around it.

Experiments with Weightlessness

Throw a stone several times and you
will see that the stronger you throw it
(i. e., the greater the velocity you impart
to it), the farther it will fly. It falls to
the ground owing to the Earth's attrac-
tion.

But if the stone reaches the circular
velocity (about 7.9 kilometres per
second) in empty space so that the
atmosphere does not hinder its motion, then it will not fall onto
the ground but will orbit round the Earth indefinitely. This revolu-
tion around the Earth is, in essence, a falling too, only it proceeds
at such a great velocity that, although the Earth attracts the stone,
its velocity does not let it fall.

These days many satellites are launched into Earth orbit. They
do a wide variety of meteorological and other scientific observa-
tions and send their results to Earth. In addition, artificial satellites
carry special apparatus to transmit over large distances television
and radio-broadcasting programmes.

What has been said about the motion of satellites also refers, of
course, to spaceships and orbital stations travelling around the
Earth. They are manned craft and much larger in size, their pur-
pose being somewhat different. Astronauts can make observations
and stage experiments that cannot be performed by robots.

Everything on spaceships, orbital stations and satellites is subject
to weightlessness, i. e., the state in which objects exert no pressure
on their supports.

In this chapter you will be concerned with weightlessness though

not subjecting yourselves to it as it is impossible to set up such an experiment at home. We shall conduct several experiments that give some idea of the way in which weight vanishes, and how some bodies and materials, e.g., liquids, behave under weightlessness. To begin with, we shall look at the phenomenon of the partial loss of weight, and then we shall also observe complete weightlessness.

But before we proceed to perform our main projects some auxiliary experiments are in order.

SEARCH FOR THE LEAST SURFACE. Given some geometric figures with the same volume, let's see which one has the least surface area. Using the simple formulas given below, you can easily work out the surface areas of some geometric figures.

Take a piece of Plasticine or clay (the clay should be sufficiently kneaded to remove the lumps) and at first mould a cube. As all the edges of the cube are equal, you only need to measure one of them. Now calculate its surface area by the formula $S = 6l^2$, where S is
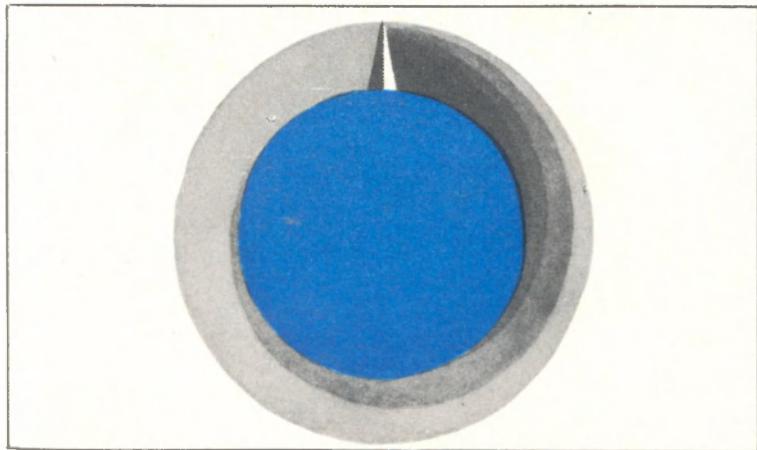
the surface area of the cube in square centimetres, l is the length of its edge in centimetres. Record the result.

Next use the same piece of Plasticine (or clay) to shape a cylinder. Its volume will be exactly the same as that of the cube because the amount of material is the same. Compute the surface area. The resultant area must include the area of the side's surface and the areas of its two end faces. Measure the radius of one end face and the height and use the formula:

$$S = 6.28r(h + r),$$

where S = the surface area of the cylinder in square centimetres,
  r = the radius of the foundation in centimetres,
  h = the height of the cylinder in centimetres.

Put down the result and mould a cone. Measure its generatrix (the length of its side) and the radius of the base. The surface of the cone we calculate by the formula:

$$S = 3.14\, r\, (l + r),$$

where r = the radius of the base of the cone,
 l = the length of the generatrix.

Write down the result and turn the cone into a ball. By rolling it between your palms you can reach a fairly round shape.

Measure the diameter of the ball using a spoke or a straight piece of thick wire. Pierce the centre of the ball with the wire and divide the diameter (in centimetres) by two to arrive at the ball's radius. If you substitute the result into the relation $S = 12.56\, r^2$ you will obtain the surface area of the ball.

The comparison of the results for all the figures reveals that it is the ball that has the smallest surface.

Of course, in moulding the figures you should seek the maximum accuracy for the figures to be as correct as possible.
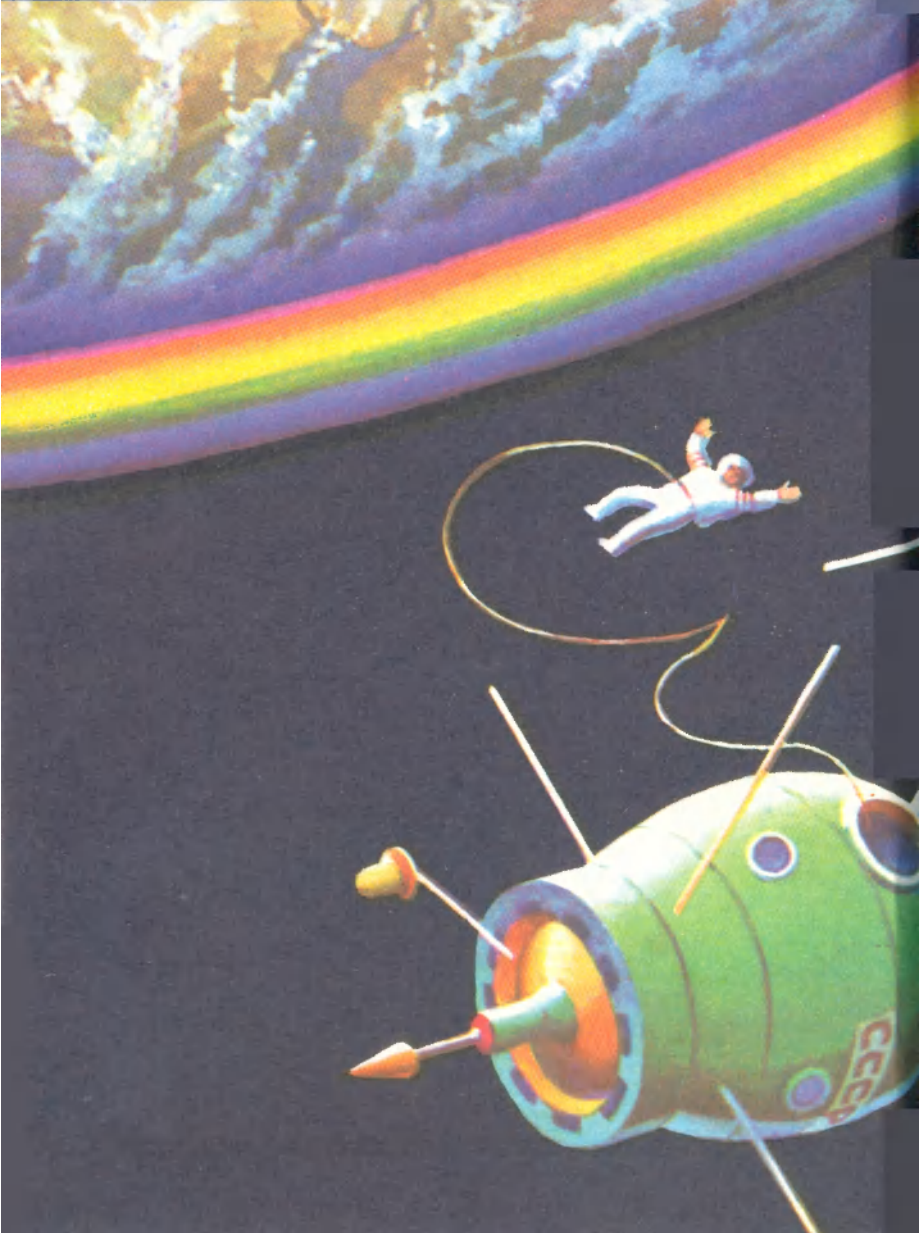
INVISIBLE FILM. Before we turn to studying the behaviour of liquids under weightlessness and carry out experiments with micro-rockets, we will take a closer look at surface tension.
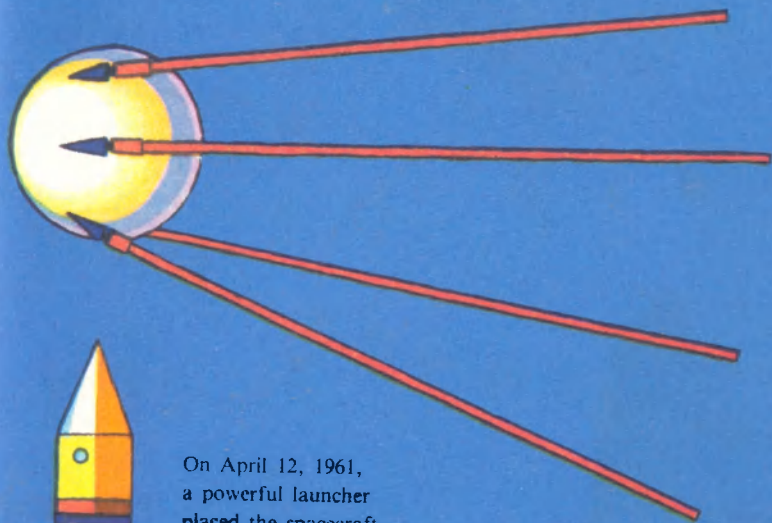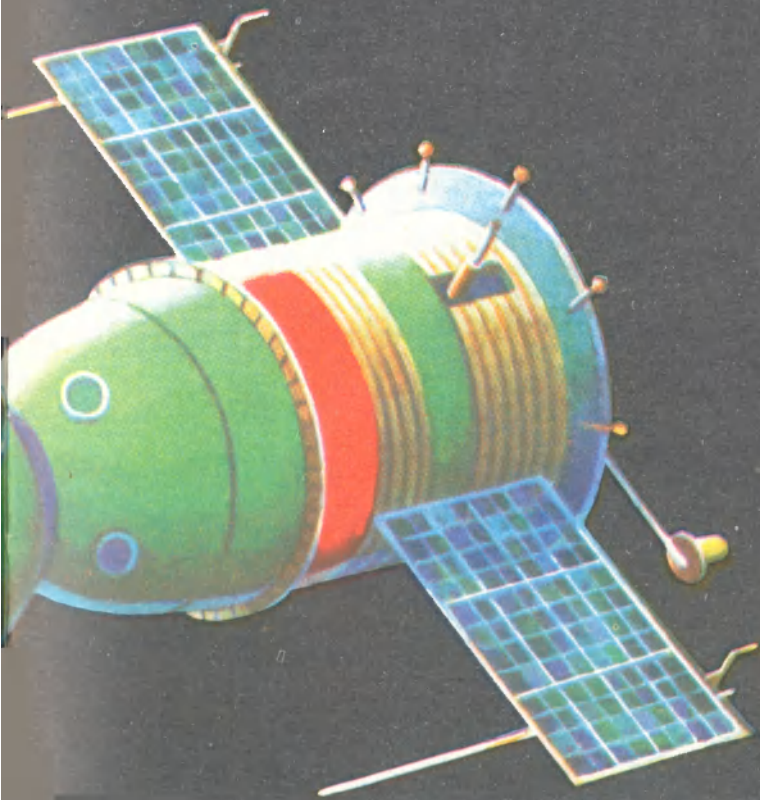
On April 12, 1961, a powerful launcher placed the spacecraft "Vostok" with the world's first cosmonaut Yuri Gagarin in Earth-orbit
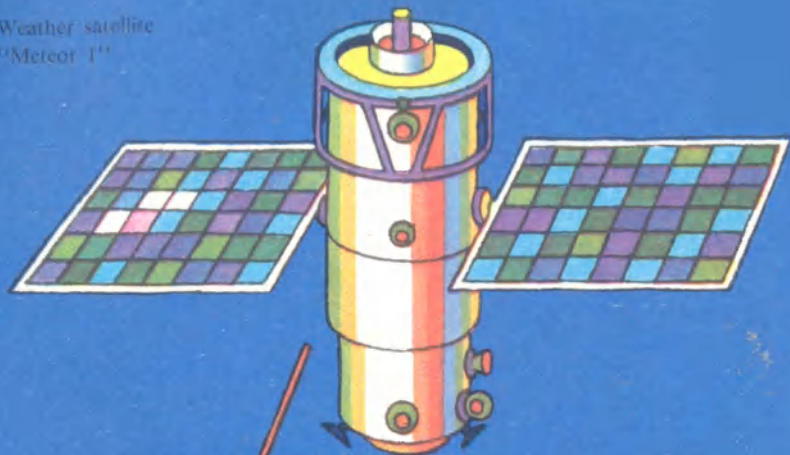
First artificial satellite

Astronaut walking in space

Weather satellite
"Meteor 1"

Research satellite
"Kosmos 97"

Measuring Satellite
"Electron 2"

It is known in physics that on the surface of any liquid there are the so-called forces of surface tension. These originate from the mutual attraction of molecules on the surface and those in the bulk. In the process, forces arise that seek to reduce the surface area of the liquid.

Fill a glass to the brim with water and continue to add water carefully with a pipette drop by drop. You will see that the water in the glass will begin to bulge above the brim as if held back by an invisible film. If you should add some more water, the "film" will yield and the water overflow.

You may have seen in summer how pondskaters "skate" about the surface of ponds or even puddles. Under their feet the water surface yields a bit, but never breaks.

Even objects, such as pins and razor blades, which are heavier than water, can lie on its surface. One need only smear them with a thin layer of fat for water not to wet them. Place the blade carefully on the surface of the water and it will float; you will see that
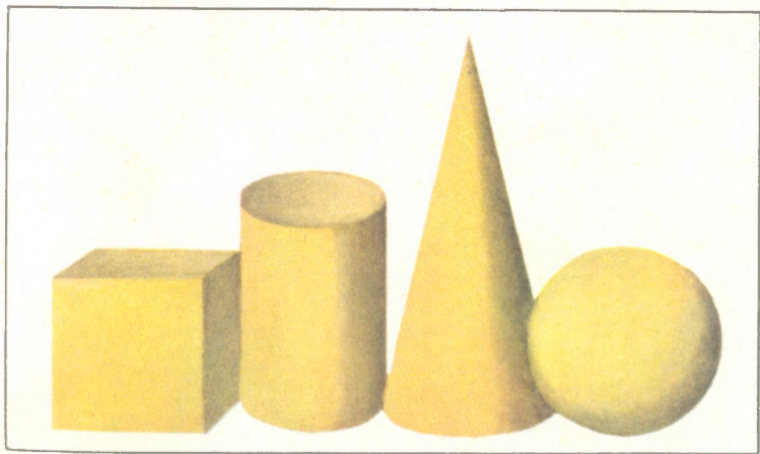
the water surface yields under the weight of the blade.

To observe the behaviour of surface tension weakened in some place, perform the following.

Apply a bit of thin talcum powder on the surface of the water in a glass. A uniform talcum surface results. Get in a pipette a bit of soapy water (it has very weak surface tension) and add one drop at the centre of the talcum circle. Where the drop falls a round dark powder-free patch will form. The soapy drop weakens the surface tension with the result that the powdered surface shifts to the glass walls.

PARTIAL LOSS OF WEIGHT. When you swim in a swimming pool, river, or sea, you feel your body become lighter, so much so that you can even lie on your back spending only a slight effort to support yourself on the surface.

We will now carry out an experiment to see how a physical body
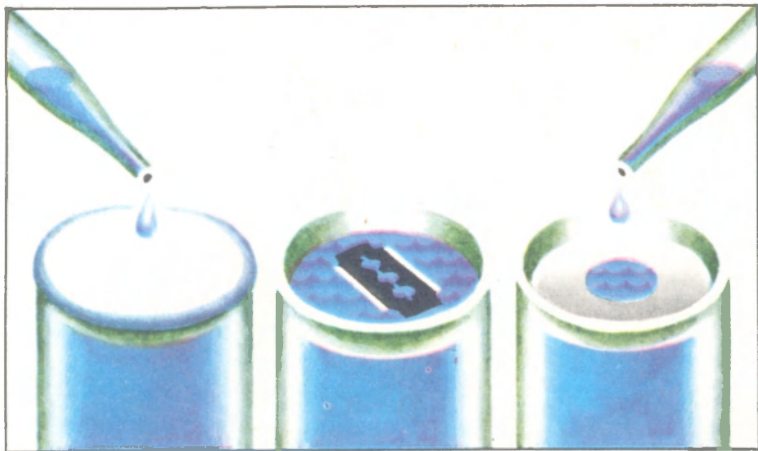
can become lighter. Take a spring balance, or if you do not have
one, adapt for the experiment a tough rubber strip attached to the
upper end of a piece of wood on which you should mark off scores
as the rubber stretches.

Attach to the balance a weight of, say, 2 kilogrammes, e.g.,
a stone. If you use the makeshift device mark off with a pencil the
extension of the rubber.

Now take a bucket filled to the brim with water and put it into
a pan. Into the bucket, lower the stone suspended from the
balance. Once the stone submerges completely, water will stop
overflowing, and the balance (or the rubber) will show that the pull
of the stone will be much weaker.

But this reduction in weight occurred at the expense of the water
expelled from the bucket by the stone. If we measure the water that
has overflowed from the bucket into the pan, the result will be
equal to the reduction in weight of the stone after immersion in the
water.
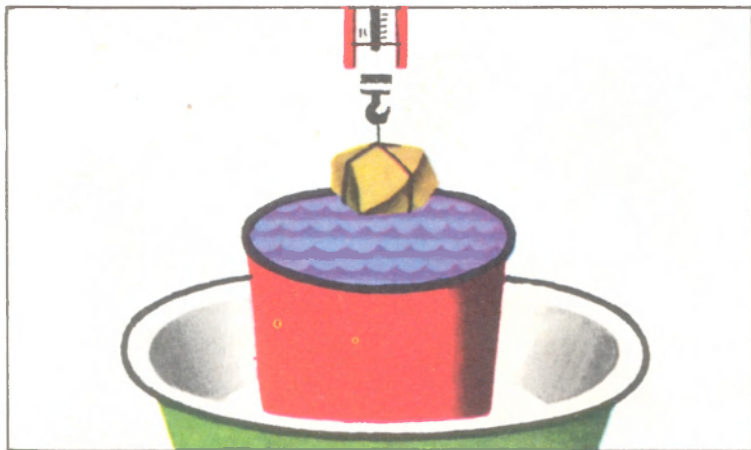
You will, of course, have surmised that this experiment illustrates Archimedes's principle.

Using this technique you can easily work out the volume of an object, if it cannot be determined otherwise. It is only necessary to immerse the object in water (of course, only if the water will not spoil it), and then measure the volume of the water that has overflowed. If the object is small, the water need not overflow, since the volume can be deduced by measuring the water levels before and after the immersion.

LIQUID BALL. You know that liquids always take the form of vessels or reservoirs containing them. A large amount of water will immediately spread under gravity if poured out of a vessel.

Well, if water suddenly becomes weightless, what form will it assume when it leaves a vessel? To begin with, consider small amounts of water–drops. Drops are very light, and gravity does not distort their ball-shaped configuration, or does only slightly,
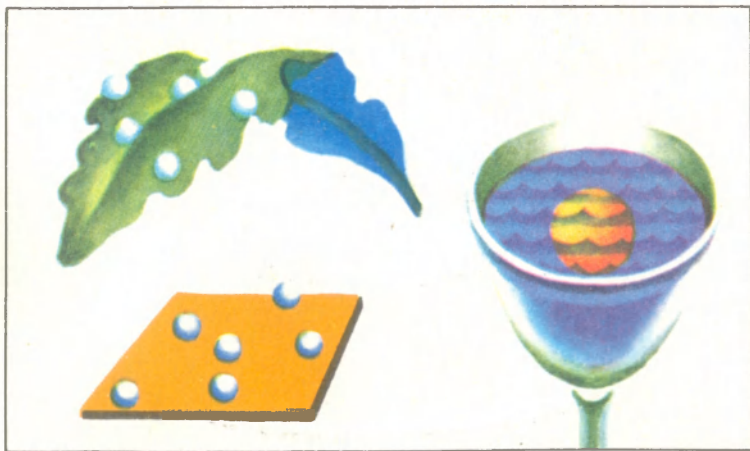
flattening them a bit. Balls of water–drops–can be observed on leaves of plants or on fabric that does not absorb water. The smaller a drop, the more like a ball it is. In the air rain drops are almost balls. In free fall they are in the state of weightlessness, and surface tension, seeking to create the smallest surface area, makes them almost ball-shaped.

Let us conduct one interesting ancient experiment. For a liquid, we will create about the same conditions that occur under weightlessness. In this experiment you will be able to observe the natural configuration of a liquid not just for small drops but for a ball with a diameter of about 2 centimetres.

For the experiment we will need denaturated alcohol (or if not available, eau de Cologne), water, some sunflower or cotton-seed oil, a pipette, and a glass.

Put into the glass several drops of the oil, and half a glass of the alcohol or eau de Cologne. Oil is heavier than alcohol, therefore it will gather at the bottom of the glass. Now begin to add water to the alcohol stirring carefully with a stick for the alcohol to mix uniformly with the water. You will soon see a small ball separate from the bottom and ascend slowly. Stop pouring water and add some more alcohol or eau de Cologne. This will make the oil ball descend a bit and "hang" in the glass at a certain depth.

This will come about when specific weights of the oil and alcohol-water mixture are equal.

Get some oil in the pipette and introduce it into the oil ball. If you do so several times you will see that the ball in the glass becomes larger each time. The best way to observe this is from above and not through the curved, distorting glass of the vessel.

If you try, with a stick, to change the form of the ball in the glass, it will, in a matter of seconds, go back to its original configuration.

The surface tension makes the oil seek the smallest surface area–that of a ball.

Let us use our imagination a little and perform a thought experi-

ment. Visualize yourself in a spacecraft under the conditions of weightlessness with a glass half-filled with water. No matter how hard you try to overturn the glass, no water will pour out of it. To get the water out of the glass you would have to shake it slightly. After fluttering about in mid-air the water would then assume a ball configuration. But under weightlessness, even a large amount of water, say, a bucketful, can assume a ball shape. And if there is no air motion, a large water ball will float about the cabin. Water, separated from the chains of gravity, would take on its natural form.

We have seen a TV programme transmitted from the orbital station *Salyut-4* in which the cosmonauts P. I. Klimuk and V. I. Sevastyanov showed the following: they let water flow from a rubber hose and water emerged in large balls. It appears that no imagination is required.

SIMPLE EXPERIMENTS WITH WEIGHTLESSNESS. Weight and gravity are not one and the same thing. Gravity is applied to the body itself, and weight is a force applied to a support on which the body lies, or is suspended. If the body falls, and it falls under gravity, it stops exerting a pressure on a support. Hence the weight has vanished – weightlessness set in.

What happens to a spring balance that is measuring weight if it falls together with the object suspended from it? It will indicate absence of weight and the pointer will be at zero.

Take a spring balance, attach a tin-plate clamp on the scale so that it could slide along the scale; suspend from the hook a 2-kg object and slide the clamp down to the pointer. Holding the balance in your hand lower it together with the suspended object. The motion should be swift and accelerated, it should simulate the fall of the balance and object. After the balance has stopped lowering, the pointer will indicate the same weight as before, but the clamp will be shifted to zero. This means that during the fast descent of the balance and object, the latter weighed nothing and was

in a state of weightlessness, thus the pointer rose to zero and shifted the clamp there where it remained.

If you have no spring balance, you can make a makeshift device by fastening to a piece of wood a tough rubber strip with a pointer and a tin-plate clamp attached to it. Markings can be arbitrary; what matters is that these begin at zero which corresponds to no weight.

One more experiment. Take two full different sized cans of preserves, and put one can on top of the other. Between the cans put a strip of paper so that its end shows. If you pull this end you will see that it is not easy to remove the paper tightly clamped between the cans – you will need some effort.

And now, spread rags on the floor to protect it and not to damage the cans, and proceed as follows. Hold the paper clamped between the cans with one hand, and with the other pick up the two cans stacked one upon the other. Let the cans go. In falling these become weightless and the paper slides out readily.
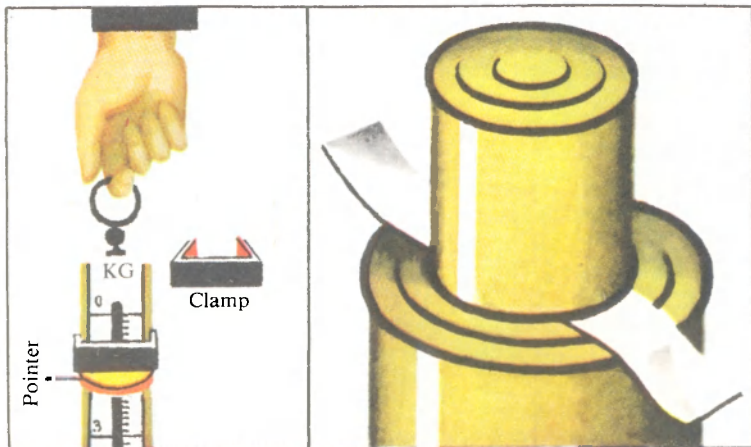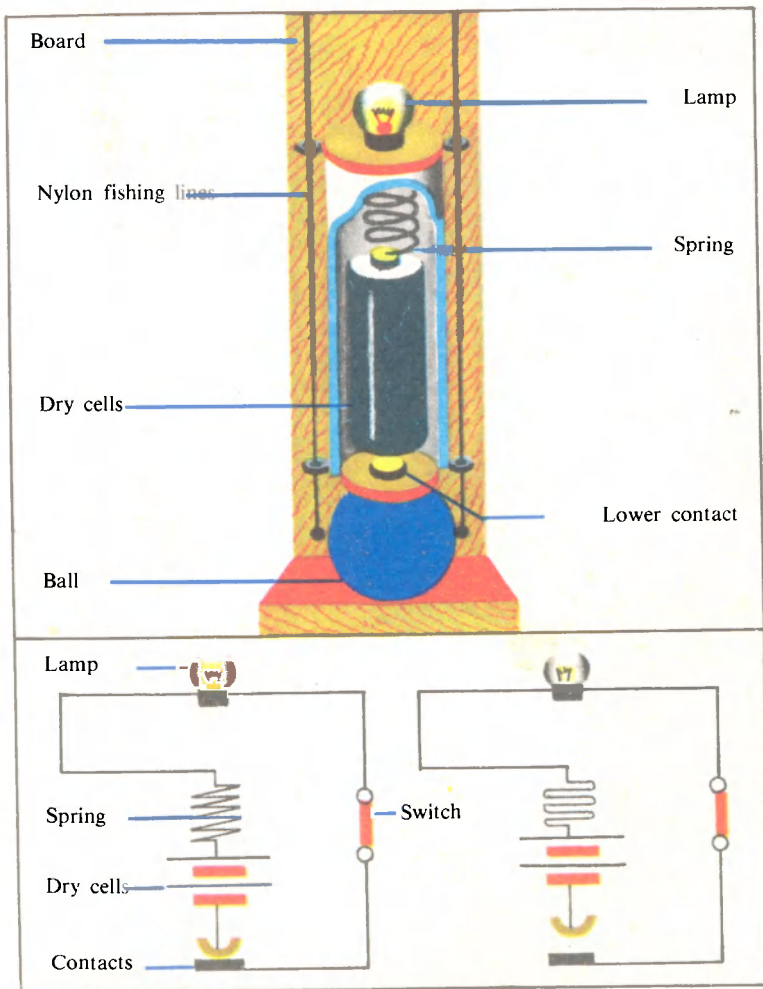
WEIGHTLESSNESS WITH SIGNALLING. If you want to make a present to the school physics laboratory, make a device that demonstrates weightlessness in free fall.

For the job you will need the skills of a carpenter, a plumber, and an electrician, as well as ability to cut and glue cardboard. So we proceed to make the device.

To make its body, glue thick paper rolled into a multilayer tube that can accept in a sliding fit two cylindrical dry cells used for transistor radios. The tube should be quite stiff. To glue it use a form that is a round, sectional (split along the axis) wooden stick one centimetre thicker than the battery, its length being two battery lengths plus five centimetres. Two caps are glued from cardboard or paper such that these slide tightly on the tube. Glue to one of the caps (say, the upper one) a small plywood ring (its diameter should equal the outer diameter of the tube) and fasten to it the contacts for a small torch bulb. To the lower contact (i.e., a brass plate) attach one end of a spring made of copper or iron wire. The spring is manufactured by winding the wire on a rod. It should be such that the weight of the two dry cells would stretch it by half of its length. Stack the cells one upon the other (they will now be connected in series) and use the lamp to see if the contact is good. Glue paper on them. Next connect to the spring end the upper contact of the cell using a wire and solder the contact through.

Inside the lower cap, glue a plywood ring and attach to it a brass contact. The bottom of the lower cell will be thrust against it when our device is assembled. Lead out the wire from this contact and attach it to the side contact of the lamp on the upper cap. Along each of the two opposite side walls of the device attach a wire loop.

Assemble the device thus: the cells must be suspended on the spring from the upper cap, the bottom of the lower cell resting on the lower contact. Screw in the lamp – it should glow. Hold the device upright with the lamp up, and then lower it quickly, not letting it go. If, in lowering, the lamp goes out momentarily and

Board

Lamp

Nylon fishing lines

Spring

Dry cells

Lower contact

Ball

Lamp

Spring

Switch

Dry cells

Contacts

comes on again, then everything is all right. Otherwise we will need to make another spring: change its diameter or wire thickness.

After the test. install the device on a prepared board 2 metres in length and 15 centimetres in width. At the end of the board make a loop so that it can be hanged vertically on a wall, and at the other end glue on a rubber ball. Along the board, by-passing the ball, stretch two taut nylon fishing lines and secure them at the top. The lines must be separated by a distance equal to the diameter of the device and passed through the wire loops on both sides. When raised, the device should not touch the board.

We now proceed to perform the experiment. Raise the device to the top with the lamp on. The glowing lamp implies that the objects suspended from the spring (the dry cells) have weight. Lower the device. When the device falls we have weightlessness. The dry cells stop pulling the spring. The lower contact separates and the lamp goes out. When the device strikes the shock absorbing ball, the weightlessness state ceases and the lamp turns on again. For the lamp not to glow unnecessarily put a switch on the side of the cylinder-wall. Then the lamp can be lit during an experiment only.

In our device weightlessness manifests itself by the fact that the lamp goes out. But, if you wish, the opposite can be made to occur: the lamp will go on when weightlessness sets in.

WEIGHTLESSNESS AROUND US. Under terrestrial conditions we often come across the phenomena of, if not complete, then partial loss of weight. But on Earth it lasts for a very short time.

Surely you have gone down in a lift. The weight loss is especially noted at the start.

And swings? When these go down, there is also a partial loss of weight.

In high diving or trampolining, when the sportsman flies through the air, his weight is completely lost, and weightlessness occurs. Perhaps you have seen acrobats flying under the circus cupula and

jumping into a stretched net. Each jump is several seconds of weightlessness.

Free-fall drops of parachute divers, when they are still falling with an acceleration, is a further example of weightlessness.

But the most prolonged state of periodic weight loss occurs in a storm on a ship. When the ship rolls the deck moves away under feet and weight is partially lost, some people have trouble with this and get sea-sick.

Thus weightlessness shows up in free fall. A space vehicle orbiting the Earth is in a state of free fall. It is subject to the Earth's attraction, and hence it falls incessantly. But it has such a velocity that it cannot hit the ground and keeps on flying in its Earth-orbit, one turn after another.

And everything inside the ship is also attracted by the Earth, but does not exert any pressure on supports because of the weightlessness. Therefore, for the astronaut it is immaterial whether he sits in a chair or flies about the compartment. You have seen many times on television pens, writing-blocks and other unsecured objects floating inside the ship.

It takes prolonged training to get used to weightlessness. And not only to get used to it, but also to work for days on end.

HEAT, THE BASIS OF LIFE. Life on Earth exists thanks to the radiant energy of the Sun, and the atmosphere. The Earth is inhabited with an infinite variety of plants and animals, and they have adapted to temperatures ranging from $+58°C$ to $-70°C$, in certain regions the temperature drops even lower.

A good example of the adaptation of living things to bitter frost is furnished by penguins. In the Antarctic penguins even hatch their young at extremely low temperatures.

Experiments with Heat

But no living creature would survive in the cosmic cold, or on the surface of Venus where the temperature can be as high as several hundred degrees centigrade.

When astronauts travel through the cosmic wastes, where there is nothing to be heated by the Sun, or to catch and reflect solar rays, and thus most bitter cold is possible, all possible measures must be taken to have the ship heated adequately.

Inside a spaceship or orbital station the air is maintained at the same pressure and composition as on Earth, and the temperature is maintained at a comfortable level. This is all provided by devices that automatically control the composition, humidity, temperature, and pressure of the tiny atmosphere inside the craft.

It is only the weightless state that makes astronauts feel that they are not on Earth, but on a tiny artificial planet created by human genius, rushing along at terrific speed through dead empty space...

HOT RAYS THROUGH COSMIC EMPTINESS. Thus, all the living things on Earth owe their existence to the Sun. What is this mighty source of life?

The Sun is a hot gaseous sphere. The scientists say that in its bowels, at enormous temperatures and pressures, continually occurs the thermonuclear reaction of conversion of hydrogen into helium.

This violent reaction is accompanied by the liberation of a colossal amount of thermal energy. The thermal energy of the Sun is radiated in all directions. The Earth only catches a minute part of it, but this fraction appears to be sufficient for life to thrive on Earth and for an enormous variety of plants and animals to exist and prosper.

And almost all the other kinds of energy, too, owe their origin to the Sun. Now the Sun is beginning to be used as a direct energy source as well. Plants are being constructed on Earth to catch solar rays, making them heat water or produce electricity directly. You know that the main source of energy on artificial satellites, space vehicles, orbital stations, automatic roving vehicles on the Moon or other planets, is the Sun. Solar energy for space vehicles is trapped and converted into electricity.

The energy of the Sun comes to us as thermal rays having covered millions of kilometres of empty space. Such a way of transferring heat without an intermediate medium is called radiation.

Try the following. Clasp the bulb of an electric lamp with your fingers. Switch the lamp on for 2-3 seconds. While it is on, you will feel heat on your palm and fingers. But once the lamp has been switched off, you will again feel the cold of the glass.

Neither the glass nor the gas, now used to fill the lamp after it has been evacuated, had time to heat. The hand was heated only by the thermal rays from the hot filament.

In earlier times lamps were empty inside that is the air was removed from them. Such lamps were tiny models illustrating the propagation of solar heat to planets through the empty space of the Universe.

But using a gas-filled lamp you could also see that the hand was heated by the rays and not by the glass as it had had no time yet to heat.

FROM THE HOT TO THE COLD. You have just got acquainted with radiation, which is a way of transferring heat in the form of

radiant energy without heating the intermediate medium. But there are other ways of heat transfer as well. One of them is called thermal conduction.

Perhaps you have touched the handle of a saucepan with boiling water. The handle, if made of a metal, would have been very hot. To be sure, nobody had heated it specially, but heat from the hot saucepan had come to the handle to heat it. The heat came through the metal gradually. In olden days this motion of heat was even compared to the movement of running water.

Different solids conduct heat in different ways. The best thermal conductors are metals. But among metals also there are champion conductors, including the so-called "noble metals", i.e., platinum, gold, and silver. These are widely used in vital devices and circuits.

To see that different metals conduct heat differently perform the following experiment. Take two teaspoons: one of silver and the other of a nickel alloy. Attach to them two paper-clips, using drops of wax. Put the spoons into a glass, so that the handles with the
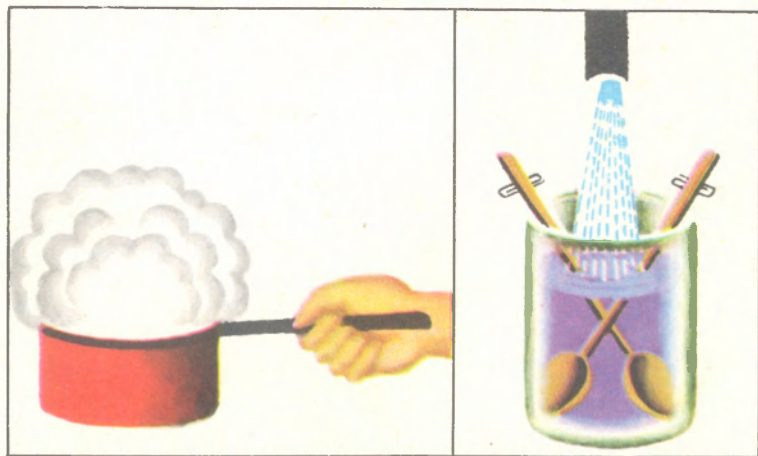
clips will stick out in the opposite directions. Pour boiling water
into the glass and the spoons will then heat. On the silver spoon
the wax will melt and the clip will fall down, whilst on the other,
the clip will either not fall off at all, or will fall later.

Of course, the spoons must be similar in shape and size. If you
have no silver spoons, take whatever is available, as long as they
are of dissimilar metals. The spoon which heats faster, is made of
a metal that conducts heat better. This metal is said to be the bet-
ter thermal conductor.

The poorest thermal conductors among solids are ceramics, pla-
stics, wood, and fabrics. This is why the handles of tea-kettles or
frying pans are made of plastics or wood. And if the handle is
made of metal, we must use a rag to protect our hands from burn-
ing. The rag, too, is a poor thermal conductor and protects our
hands, i.e., is acting as heat insulation.

WEIGHT AS A HEAT CONTROLLER. In nature there is one
more way of heat transfer, convection. It is observed in liquids and
gases, and is based on the fact that sections of liquid or gas in
heating become lighter and rise, whereas colder, heavier layers sink.
A source of heat is generally placed below, and therefore the
heated layers continually shift up and the cold ones down. But in
weightlessness, e.g., inside an orbital station, such a way of heat
transfer does not work. Absent here is the weight that acts as the
heat controller.

To observe convection in liquids conduct the following experi-
ment. Take a smooth metal plate, e.g., a plane metal cap of a glass
jar of preserves, and place on it several crystals of potassium per-
manganate. Cover them with a drop of water and a thin layer of
wax. Stick the edges of the wax cake carefully to the plate. Pour
some water into a glass and cover it with the plate so that the wax
cake will be inside the glass. Holding the glass with your hand turn
it upside down, and place the plate with the glass on two supports,
so that you can put a candle under the middle of the plate.

Put a burning candle under the part of the plate with the wax. The cake, on heating, will break away from the plate, and a flow of hot water tinged with violet will shoot up. You will see a circulation of stained flows of water: warm streams going up, and cold ones, coming down.

There is an experiment demonstrating the circulation of warm air flows that is carried out as follows. Take the glass of a kerosene lamp, or if not available, a milk bottle with the bottom cut off evenly.

Put the lamp glass over a burning candle. The latter will go out quickly, because there is no access of fresh air to it: the hot air with the combustion products sours upwards and blocks the way for the fresh air. If you insert a strip of strong paper into the glass as shown, it will separate the inner space into two halves. The one with the candle will have hot air with the combustion products that will still go up. Whereas the fresh (colder) air will come to the candle from above, on the other side of the partition.
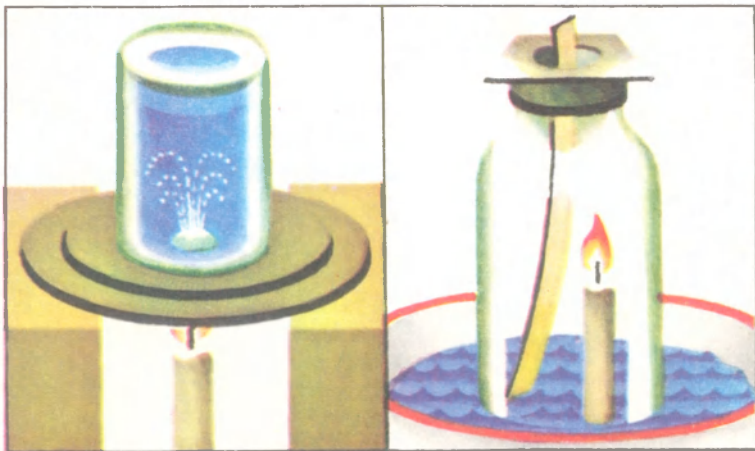
To see that the partition plays a vital role in supplying fresh air to the candle and that without it there will be no air circulation, remove the partition. The candle will immediately go out.

BARRIER AGAINST HEAT. On a frosty winter day going out into the weather you use heat insulation or, put another way, you have your overcoat on. The air trapped between the fibres of the wool or fur cannot circulate from the warm to the cold parts, and air itself, just like any gas, is a poor heat conductor. Therefore in a bitter frost it would take a lot of time before you felt that your fur coat had stopped to keep out the cold.

It should be emphasized that a fur coat never heats – it only helps retain the heat we give off.

Thus, to protect something from the cold, thermal insulation is applied. But excessive heat also requires some protection. When a manned vehicle returning to Earth re-enters the atmosphere at enormous speed, its walls are strongly heated by skin friction with
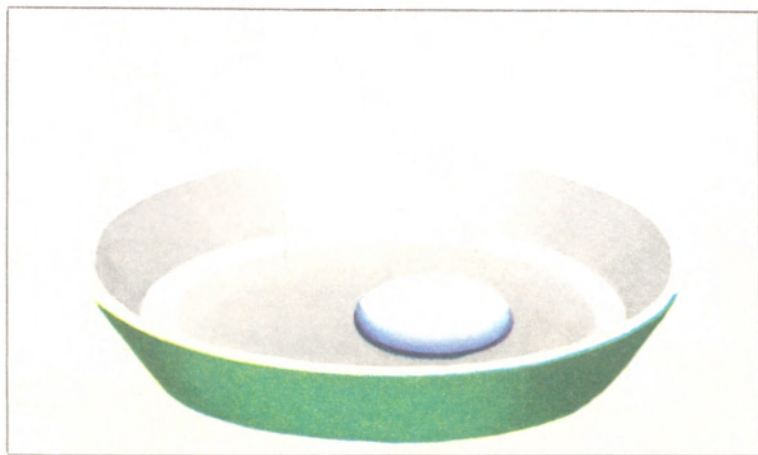
air. To protect the crew of a vehicle, and the devices of an automatic station travelling near the Moon or another planet, a heat-insulating, heat-resistant hood is used. It consists of layers of materials that conduct heat poorly, materials that are able to withstand high temperatures.

It has already been said that gases are poor heat conductors. To see that this is so, you could perform the following experiment.

Take a toy aluminium dish, put it on a small fire and, after it has heated sufficiently, pour a half-teaspoon of water on it. The water will not evaporate immediately, as expected. It will roll as a flat ball – a spheroid – to the lowest place on the dish and stand still there on the hot metal. Curiously enough, the water does not vaporize at once. Admittedly, water does evaporate, but it is this very vapour into which the water is turning, that protects the large spheroid drop from the hot metal. In this case the vapour appears to be a splendid insulation.

This experiment can also be conducted in a simplified version.
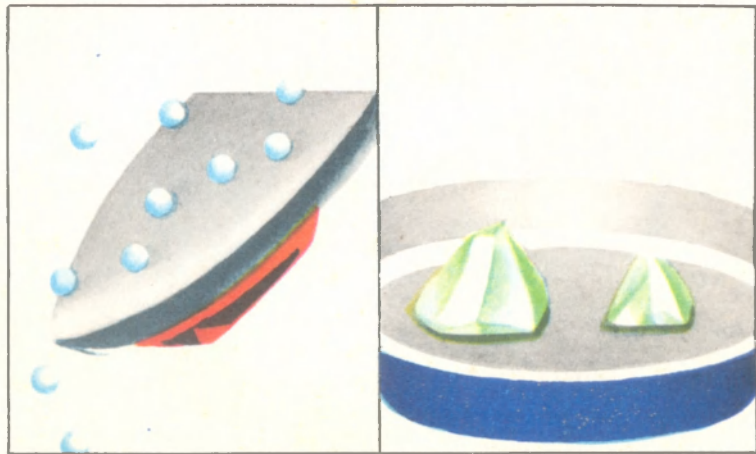
One day, when you are ironing, turn the iron upside down and, if it is hot enough, sprinkle some water on it. The water will immediately turn into small round balls that will scuttle around the hot surface of the iron. These small ball-shaped drops, too, do not evaporate at once, being protected from the heat by the vapour layer, the "vapour cushion". It is on this cushion that the water balls travel over the hot iron.

Today there are vehicles that travel on an "air cushion" (hovercraft) staying just above ground or water. Powerful blowers directed downward create such a dense "air cushion" that it supports the weight of the vehicle and crew. In our experiment something analogous takes place. Only here we have not an air cushion but a "vapour cushion" created by the hot surface of metal.

Perform one more experiment.

Take several pieces of dry ice and put them on the smooth surface of an aluminium plate, as shown. Incline the plate in various directions and the pieces of dry ice will easily slide over the smooth surface. The warm surface of the aluminium plate (its temperature differs from that of the ice by at least 100° C) helps the carbon dioxide to evolve violently. Under the pieces of dry ice "carbon dioxide cushions" will develop that are responsible for the sliding.

EXPANSION IN HEATING. It is common knowledge that bodies expand in heating. In thermometers mercury or stained alcohol is contained in a small bulb. On heating the mercury or alcohol expands and moves up a very thin canal to form a growing column. On reaching a thermal equilibrium, the column stops growing and the scale indicates the ambient temperature.

One more example of the expansion of bodies on heating. Sometimes a ground-glass stopper gets stuck in a bottle. It would be dangerous for you to apply too large a force for fear of breaking the neck and cutting your hands. Therefore a proven procedure is used: a burning match is brought near the bottleneck and the bottle is turned to warm the neck uniformly. The flame of a single

match will be enough for the glass of the neck to expand on heating and for the stopper, that had no time to heat, to be removed easily. These are examples of the use of the physical law in household. We can carry out experiments showing vividly how metals change their length in heating and cooling.

Cut a notch in a wooden circle or block, stick a needle into one edge, and place the eye of the needle on the other side of the notch, as shown. Into its eye insert another needle and drive it slightly into the wood. Bring a burning candle near the first needle. The needle will get hot, elongate a little bit, and move the second needle inserted into its eye.

Make a thermal balance by taking a piece of straight copper wire 1-2 millimetres thick and about 40 centimetres long. Then stick one end of the wire into a hole drilled in a wooden stick of about the same length and suspend the resultant weigh beam at the middle from a string. Balance the stick either by shortening it or, by suspending small weights to it, e. g., pieces of paper. You can also
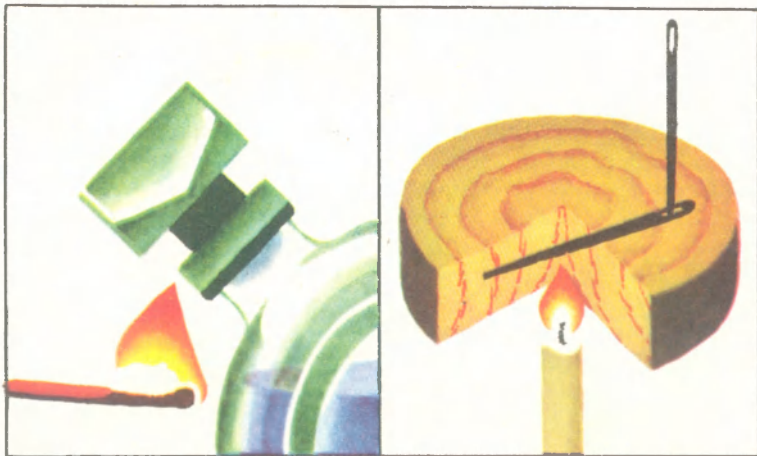
achieve the equilibrium by shifting the suspension point on the beam. Illuminate the beam with a desk lamp so that one end, e. g., copper one, casts a shadow on a wall where you should attach a piece of white paper and mark, in pencil, the position of the shadow when the beam is strictly horizontal.

Next take two burning candles and place them under the wire, as shown. When the wire warms up enough, it will elongate, thus upsetting the balance, because of the change in the arm ratio. The end of the wire will go down by several millimetres and this will be well seen from the shadow on the wall. If the candles are removed, the copper wire will cool down, become shorter, i. e., as before the heating, and the beam of our thermal balance, or rather its shadow, will return to the earlier mark.

REFLECTION AND ABSORPTION OF HEAT. Thermal and light rays are best reflected by a mirror surface, slightly worse, but also sufficiently well, by white and, in general, light surfaces.
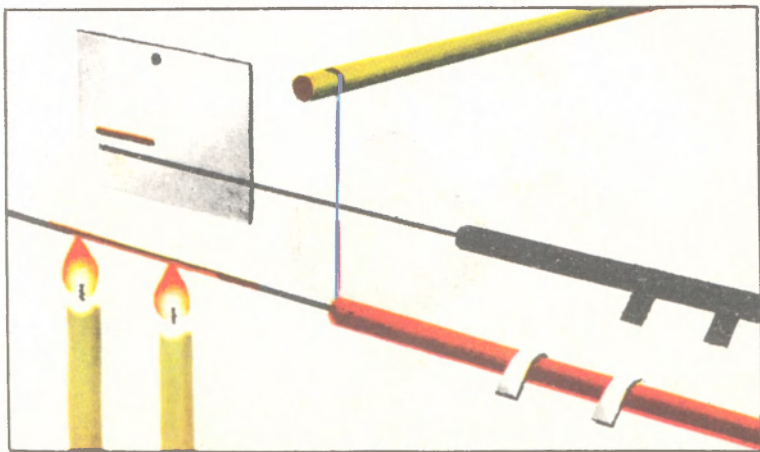
Therefore, in summer, especially in southern regions where there is plenty of sun, people prefer to wear light clothes. Dark clothes, even if made of a thin fabric, absorb thermal rays better and hence we feel hotter in them. Note that in spring the snow that is covered with dust and soot melts much faster than the pure snow in the fields.

We can perform an experiment to illustrate this. Glue a piece of strong paper into a cylinder 5-6 centimetres in diameter, then on the inside paint with India ink a spot the size of a match box. The spot can be any shape. Attach two similar coins with melted wax to the outside of the cylinder at the same level. One coin must be in the middle of the place where the ink covers the inside, and the other, on the opposite side of the cylinder. Put the cylinder over a burning candle. Its flame must be at the centre of the cylinder on the level of the coins.

To allow the cylinder to be slided conveniently over the candle, fasten onto the candle a cardboard ring with several openings for
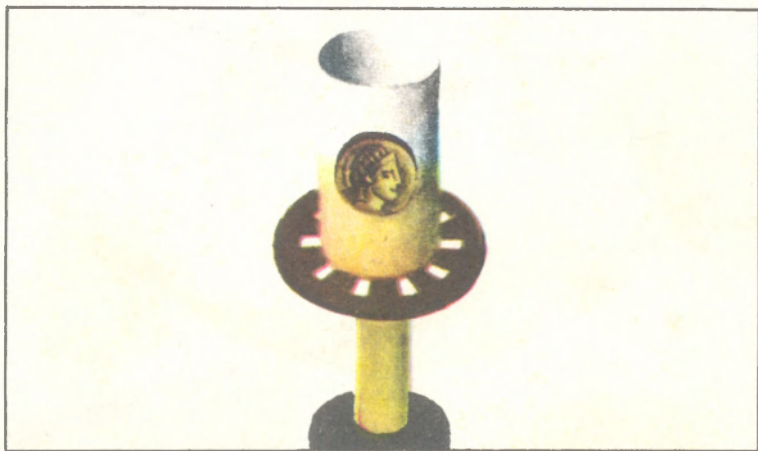
ventilation. The ring must be a tight fit over the candle so as not to slide down under the weight of the cylinder.

No matter how many times you perform the experiment, the first to fall down will always be the coin attached to the part of the cylinder painted black inside. The black surface of the paper absorbs thermal rays better, hence it gets warm faster.

EXPERIMENTS ON ENERGY CONVERSION. You know that potential energy is expressed in terms of the work that something or somebody (e. g., a machine) is able to do.

A clock spring that is not wound can be said to possess no energy and therefore the clock does not operate. You have only to wind the spring and the cogs inside the clock begin to rotate, the hands beginning to travel round the face. The spring will work only as long as its energy reserve lasts, then the energy will need to be replenished by winding the clock.

Energy exists eternally, it does not disappear and only changes
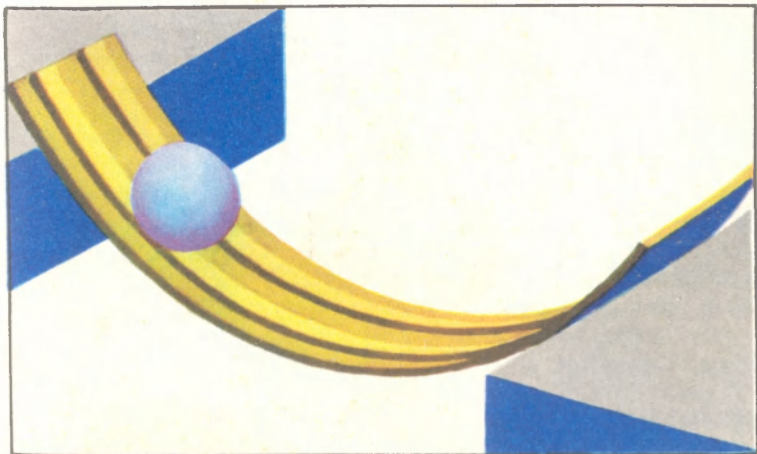
from one form into another. When the clock stopped, this did not mean that the energy of the spring disappeared completely. It was not wasted, but gradually transformed into the mechanical energy of the cogs, which in turn was transformed into thermal energy. Admittedly, the thermal energy here was minute, and it went into heating the air. The fact that we did not catch it did not imply that it was nonexistent.

Now to the experiments on energy conversions.

Onto a long, narrow cardboard strip glue two strips of thick paper leaving a small gap between them. Bend the cardboard strip and put it between two thick books. Roll a metal ball along the groove. At first, it will move quickly but, having undergone several oscillations, will stop in the long run. At the beginning of the experiment the ball possessed a potential energy, but when you let it go, the potential energy was transformed into the energy of the motion along the arch-shaped groove. In motion the energy of the ball went to overcome the force of the friction against the groove surface and air, and this friction generated heat.

A steel ruler, if bent, acquires some mechanical energy and is capable of performing mechanical work. When it straightens quickly, it can throw, say, an eraser through the room.

In pumping a bicycle tire, the pump gets warm. The mechanical energy of the air, compressed in the pump, has spectacularly been converted into thermal energy.

Every day you observe energy conversions. The chemical energy of fuel turns into thermal energy, and further into mechanical one. This occurs in the automobile, diesel locomotive, and airplane. The same conversion also takes place during the launch of a spaceship when the engines are operating.

Here is still another interesting experiment of mechanical-to-light energy conversion.

Take a lump of sugar (but not quick dissolving) and a pair of pincers usually used to pull out nails. The experiment is conducted in the dark, when your eyes have become accommodated. Cut

sugar with the pincers and observe what takes place in the process. At the instant the pincers cut the sugar at the fracture a bluish glow can be seen. This is a flush of cold light. This cold glow appears in the fracturing of crystals and is ornately dubbed triboluminescence.

LIGHT-TO-ELECTRICITY CONVERSION. We convert electricity into light habitually. We only need turn on the switch. But there is a phenomenon in which light is converted into electricity. This phenomenon is known as the photoelectric effect. It was studied late in the 19th century by the eminent Russian physicist Alexander Grigoryevich Stoletov. He found that if a zinc plate is exposed to the bright light of an electric arc, then an electric current will flow through the circuit in which the plate is included. This discovery underlies the use of the photoelectric effect these days. It is widely used both in industry and everyday life, the sound in the cinema, and television both owe their existence to the photoelectric effect.

Sun's rays

Solar cell

Solar cell panel

"Molniya-1" satellite
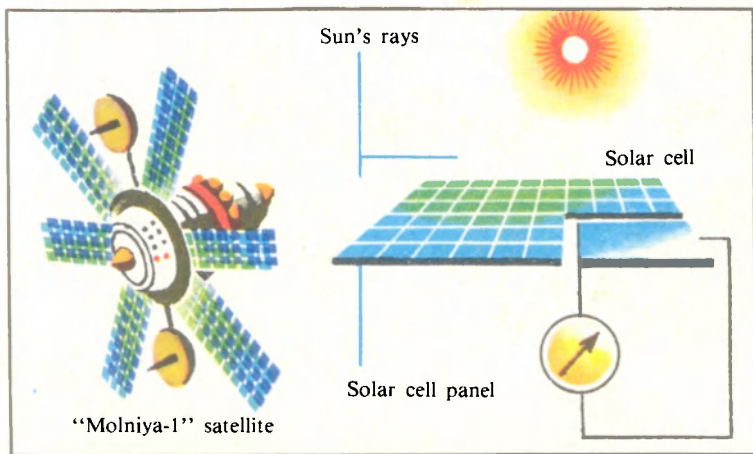
But the photoelectric effect is not just an amplification of electric current through the exposure of some metals connected to an electric circuit. This effect can also manifest itself in another way. In certain semiconductors, when exposed, an electric current appears which was not observed before. The energy of light in them turns into electrical energy.

One of the applications of this phenomenon is in the photographic exposure meter used to determine the exposure in taking pictures. You may observe, holding a meter in your hands, how its pointer swings when the device is directed at bright objects.

Solar batteries on spaceships, satellites, lunar roving vehicles, and orbital stations provide the required electric energy. You have often seen them on photographs and drawings. These are normally several panels on which semiconductor elements are arranged. Solar light that is incident on these elements produces in them an electric current.

THE SPACE EXPERIMENT OF JULES VERNE.

The heroes of the novel *Hector Cervadac* by Jules Verne got on an asteroid. They named it Gallia.

The asteroid travelled through space, farther and farther from the Earth. On it there were several people. We will retell one episode from the life of these colonists.

The colonists lived on an island surrounded by water that did not freeze, though the temperature was well below freezing point. The water was still, not a sign of motion. The captain asked a small girl, one of the crew, to throw a piece of ice into the sea. The instant it touched the still water of the sea the water turned into ice with a deafening crack.

Only the scale is fantastic here, but the essence of the phenomena is real and scientific.

Crystalline substances melt and solidify at one and the same temperature that is constant for a given substance (provided the pressure is constant).

So, ice melts at 0°C.

For ice to melt, it is necessary to heat it to 0° C and continue to supply heat. This additional heat goes into breaking the bonds between molecules forming the ice crystals. But in the course of melting the temperature will maintain at a constant level, at 0° C.

Water changes into ice at the same temperature of 0° C, and this temperature does not change until a given amount of water freezes.

But water, just as other liquids that solidify into crystalline structures, has an impressive property – it can be supercooled down to a temperature much below zero. In the process the water should not be subjected to jerks.

We will carry out the experiment described by Jules Verne, not with water but with a substance that is more convenient to experiment with, and also in a much more modest scale. We will experiment with hyposulphite, a crystalline substance used in photography as a fixer. The hyposulphite should have large crystals and be dry.

Fill a glass phial with hyposulphite crystals. Next place it in a saucepan with warm water and begin to warm the pan. What is required is that all the hyposulphite should melt to turn into a transparent liquid. To this end, tilt the phial from side to side but so that water does not get into it.

Make a stopper of paper and pass the glass tube of a pipette through it. When the phial is stoppered, the narrow end of the tube must dip into the melted hyposulphite. The tube has its outer end plugged with cotton wool to keep away foreign materials. Put the phial in a place where it will be protected from shocks.

After a time, about 2-3 hours, the phial will cool down to room temperature. Carefully remove the cotton wool and drop into the tube a crystal of the hyposulphite, big enough to stick in the narrow end of the tube.

Under your very eyes a fast crystallization will develop through the whole contents of the phial. The hyposulphite will solidify at once, turning into crystals.

But the most curious thing is that the phial that a while ago was cold will now be hot. You know that the fusion and solidification of crystalline substances always occurs at the same temperature. Here the thermal energy is liberated as a result of the fast restructuring of the hyposulphite molecules in transforming from the liquid into the solid state.

INERTIA AROUND US. We often hear and use the word *inertia*. It is even used by those who do not know or have forgotten Newton's first law of motion.

Inertia is a Latin word. It means languor, laziness, and sluggishness. People say of a lazy, inactive man: "He is very inert." This is the literal meaning of the word.

Experiments with Laws of Motion

But in physics it is employed when they want to describe a definite property of a body; when they want to say that a body, be it a stone flying through the air or a railway carriage rolling along rails, moves on its own even when not subjected to a driving force.

On the contrary, if a body is at rest, it will not move and for it to do so, a force is required.

Thus, each body possesses an ability to retain its initial state, either rest or rectilinear uniform motion, unless a force makes it either stop or divert.

Consider household appliances illustrating the phenomenon of inertia. When, after cleaning, you shake out a dusty rag, observe the way in which dust flies out of it. The dust leaves the rag adequately when you strike it hard, say, on a pole. In the strike the rag stops abruptly, and dust flies off by inertia, as shown.

When you empty a glass, you can jerk it with your hand. The water, by inertia, moves on, splashing out of the glass.

When we prepare a medical thermometer for measurement, we shake it hard several times. Then the mercury column, by inertia, descends into the bulb.

Observing attentively the world around you, you yourselves can furnish scores of examples of inertia. For instance, when you ride in a bus, tram, and other vehicle, and the vehicle stops abruptly, you experience a jerk as if pushed forward by some unknown force.

Inertia is widely used in industry and transport. When a boat

approaches a pier, the propellers usually are not operating and the boat moves by inertia to its berth.

Sometimes inertia must be fought with. For instance, a landing plane flies by inertia but its velocity is still too large and must be reduced using special brakes.
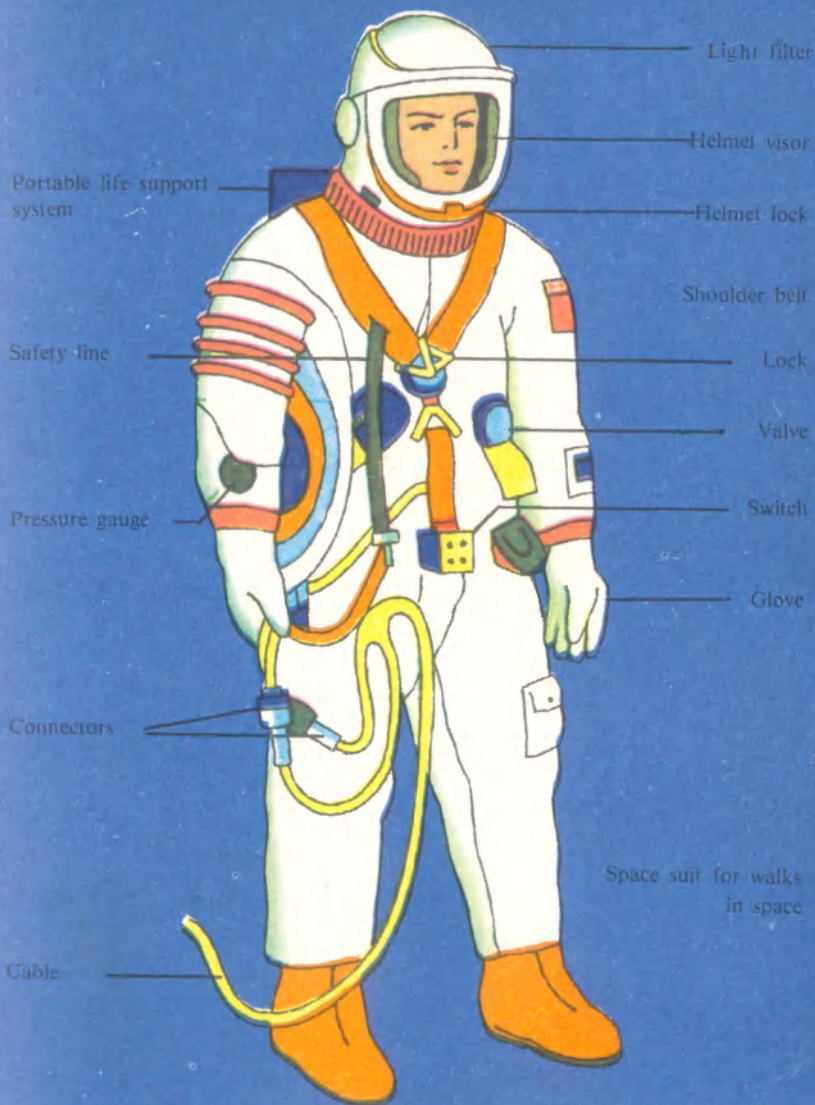
When astronauts return to Earth speed must also be reduced before the parachute is deployed.
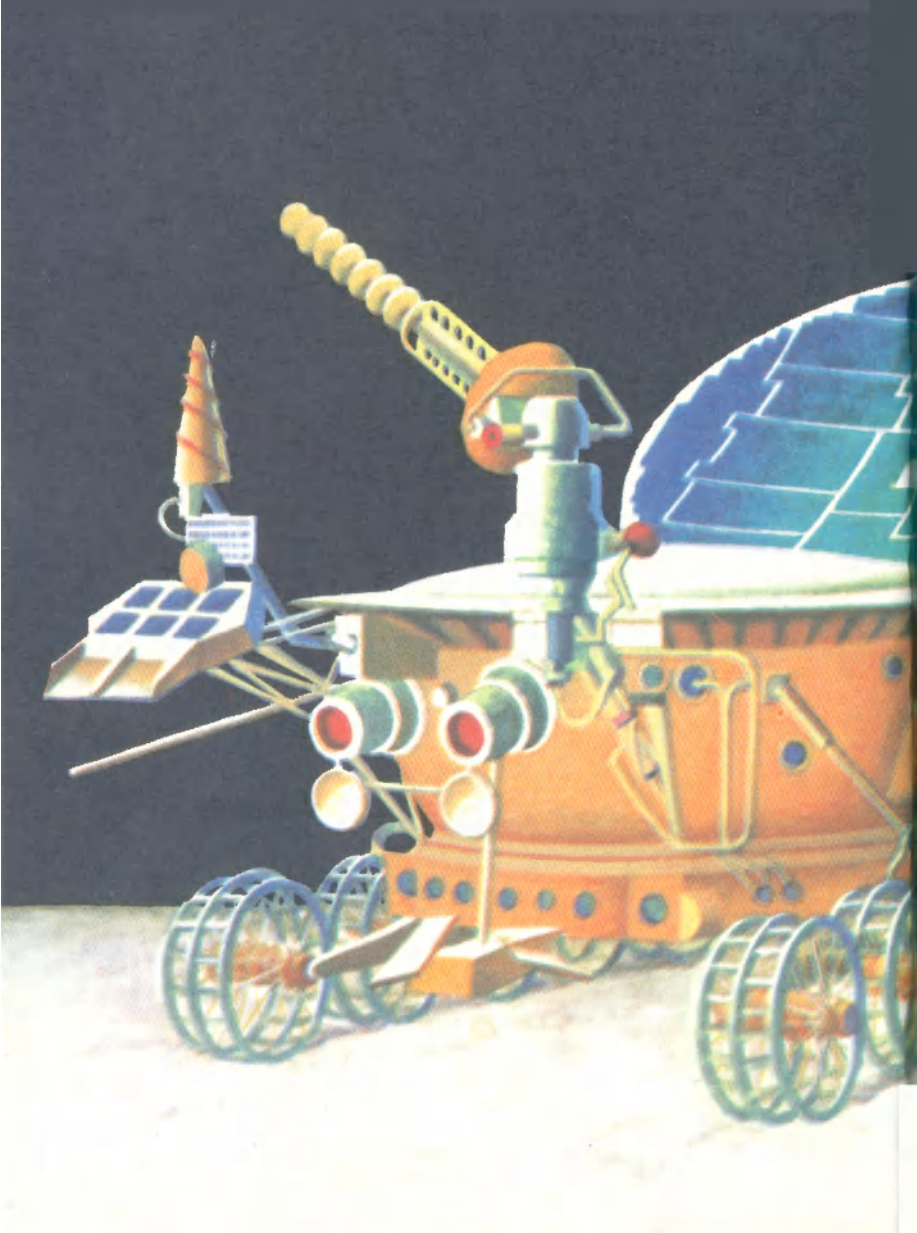
EXPERIENCE OF MOTION "UPSIDE DOWN". P.N. Nesterov was a brilliant Russian military airman, the founder of aerobatics. He was the first to perform, in his aeroplane, a stunt later called after him, "Nesterov's loop". An aeroplane accelerates, dives, climbs sharply, rolls on its "back" to complete a closed loop in the vertical plane. Inertia in this manoeuvre plays a significant part.

Decades ago a circus number with a cyclist who travelled a part of his route "wheels up" was a great success with the public. The track, along which the cyclist travelled at great speed, having zoomed down from a height, was formed into a loop in the vertical plane. It was within this plane that the cyclist spiralled. On the upper curve he was moving upside down, thereafter rolling safely down; the public sighed with relief.

The trick just described resembles Nesterov's loop. For the number to be a success, the bicycle must develop a high speed, e. g., by rolling down from a height, the starting point being much higher than the top of the loop. The cyclist moves in a vertical ring like a stone whirled on the end of some string. Thus the stone pulling at the string when at the top of the orbit does not fall down. In much the same way, the cyclist is pressed to the ring track and does not fall when travelling upside down.

In our household experiment there will be neither pilot nor cyclist, instead we will use their modest substitute – a steel ball (a ball bearing).
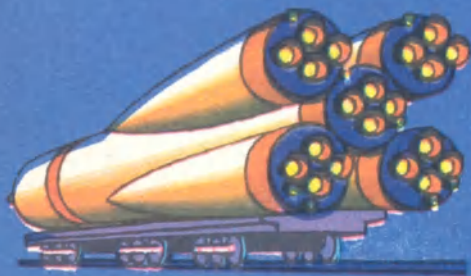
Light filter

Helmet visor

Helmet lock

Portable life support system

Shoulder belt

Safety line

Lock

Valve

Switch

Pressure gauge

Glove

Connectors

Space suit for walks in space

Cable

The moon car "Lunokhod 1" on the Moon

Rocket transported to launch site

Principle of rocket motor

Fuel supply

Coolant inlet

Frame

Gas generator

Oxidiser valve

Main chamber

Liquid-fuel motor of "Voskhod" and "Vostok" ships

Fuel valve

Steering motor

A track with a vertical loop can be manufactured to suit the size of an available ball. Suppose you have a steel ball 9 millimetres in diameter. Take some strong drawing paper or thin cardboard and cut out a strip 2.5 cm wide and 120 cm long (if such a length of paper is not available, two or three pieces can be glued together). Along the entire length of the paper strip bend the edge surfaces up 7 millimetres high, to obtain a long groove. Now, at one end make a loop 8 centimetres in diameter. In order to be able to bend the loop, along a length of 26 centimetres cut V-shaped notches in the edges with scissors at 3-4 millimetres intervals. Then you bend this part of the groove into a regular circle. In so doing, slightly twist the ends of the loop and glue them to a piece of cardboard to fasten them, as shown.

Now assemble the model. If you have worked accurately, you will have a beautiful structure that could be taken to the school physics lab to be used as a visual aid.

Install the paper loop vertically. Secure the end of the 90-cm

Loop section
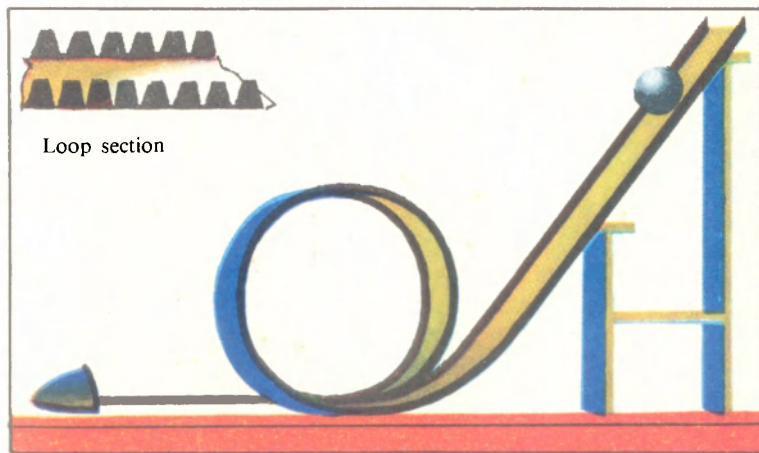
groove at a height of 40 centimetres (from the base of the loop). Descending steeply and smoothly, the groove should equally smoothly pass into the loop. To the other end of the loop, so to speak, the outlet, glue a similar groove, but only 20 centimetres long. At its end make a paper "pocket" (trap) for the ball so that after each run you should not need to hunt for the ball all over the room.

See to it that the structure is sufficiently rigid and does not yield under the weight of a ball, and that the track is smooth, having no indentions and burrs.

When the arrangement is ready, you can launch the ball from the top of the groove. The ball begins to roll, gains adequate speed and inertia, passes the top of the loop, rolls down, and ends up in the trap.

When performing the experiment, try changing the height from which you launch the ball and observe its behaviour. Note the critical height, i. e., the one at which the ball will not be able to go all the way along the loop.

The experiment can be improved by adding one more, smaller loop for the ball to run through the two loops before being trapped.

LUNAR EXPERIMENT. We often use the word *mass* but do not always conceive the notion correctly. Given below is a passage from the book *Foundations of Elementary Physics* by Yu.A. Seleznev:

"Unfortunately, obscurity and looseness of introduction and usage of the notion of mass is a frequent occurrence. Sometimes one hears of the overflow of a mass of liquid from one vessel into another, of a mass suspended from a piece of string or lying on a table, and so on. Such phrases are absolutely devoid of physical meaning and to a great extent make the essence of the notion of mass being obscured.

The mass of a body is, above all, its *property* to respond with

a definite acceleration to the action of a force. The statement that
the mass of a body is a measure of its inertia means just the same."

Further, "If mass is a certain property of a body, then, just like
any other property, it cannot "hang", "lie", "flow", be touched or
put in a pocket. It would occur to nobody to suspend from a string
the whiteness of snow or transparency of water, but mass *is* for
some reason *suspended*!"

Weight is determined using a spring or beam balance. The unit
of weight is, as you know, the kilogramme. Mass is also deter-
mined using a beam balance, but here the mass being measured is
compared with the standard mass of one kilogramme.

Let us carry out a thought experiment. We are on the Moon and
have brought along a packet containing six kilogrammes of sugar.
Weighing this sugar on the Moon with a spring balance shows that
the package contains only... one kilogramme. But if we were to
weigh the sugar not on a spring, but on a beam balance, the sugar
in one pan and a six-kilogramme balance mass on the other, we
would see that everything is all right – the sugar is here. It is the
weight that decreased, the sugar becoming six times lighter because
the Moon is smaller than the Earth and its attraction force is six
times weaker. As to the property of the sugar packet to accelerate
under a force, it is exactly the same as on Earth.

Weight can decrease, it can even vanish (when the sugar packet
was travelling in the rocket to the Moon, it weighed nothing at all),
but mass does not vanish – ever!

EXPERIMENT WITH INERTNESS. You have already seen what
an interesting phenomenon inertia is, and every material thing in
nature possesses the property of inertia.

Doing several experiments, we will observe the ability of several
bodies to react or respond by accelerating to a force applied to
it.

Suspend from strings two similar cardboard boxes: one empty
and the other filled with sand or clay. To the bottom of each box

tie some more string. If you tug sharply at the lower string on the empty box, then any one of the two strings would break: either the one from which the box is suspended, or the one at which you have pulled. The inertness of the empty box being negligible, the pull was felt by the both strings equally. But the filled box behaves otherwise. When the lower string is jerked, it alone breaks. The filled box is very inert, it is not able to transmit the pull to the upper string, and therefore the lower string will of necessity break.

Have you ever fixed an axe on an axe-helve? This is done as follows: you take the axe-helve in your left hand and slide the axe as far as it will go. Then with a hammer you strike the other end of the axe-helve. The steel axe has a larger mass, and hence larger inertia, than the wooden axe-helve, therefore the axe reacts but weakly to the strikes. Being less inert, the axe-helve is driven home more and more by each stroke despite the strong friction.

For our next experiments we will need a stack of draughts or coins of the same size. With coins, the stack should be placed on
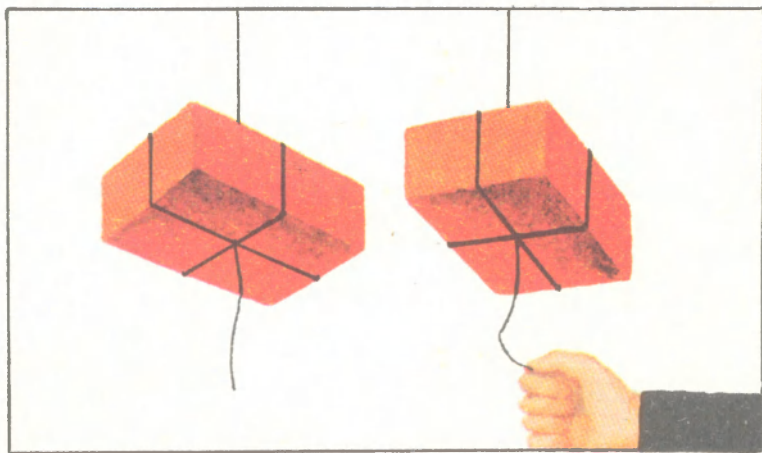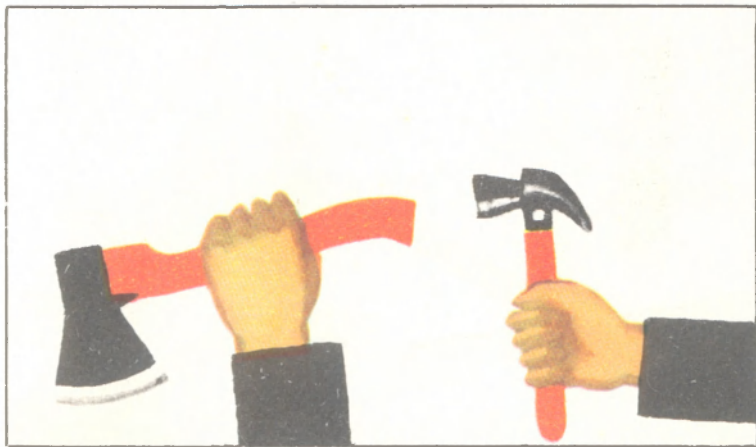
a large coin lying on a smooth surface. You will also need rulers:
a wooden one with draughts and metal one with coins.

With a sliding slash knock the lower draught (or coin) out, as
shown. The stack will remain in place due to its inertness. The
knocked-out draught "had no time" to transfer to the rest of the
stack the velocity imparted to it.

This attraction has amuzed the public as early as the turn of the
century. Here is one more entertaining experiment of those days,
but it requires some preliminary training.

On the edge of a smooth table place a narrow strip of paper (2-3
centimetres wide), one end of the strip dangling. On the other end
put a large coin, as shown. The coin must have a milled edge and
should be balanced perfectly upright. Now snatch the paper strip
from under the coin. With some experience your coin will not so
much as stir. The coin, just as any other material body, possesses
some inertness and the jerk could not impart acceleration to it and
set it in motion. In carrying out the experiment, observe the be-

haviour of the coin as you vary the speed with which you snatch the strip.

EXPERIMENTS WITH THREE BRICKS. These experiments somewhat resemble the trial with the two boxes.

Suspend from a crossbar at a string both a single brick and two bricks tied as shown. We thus have two "physical bodies", the inertness of one being twice that of the other. With your little finger, which is the weakest one, try to push first the single brick and then the doubled bricks. The same effort will not displace them at the same distance.

To see this better, tie to both pendants a similar piece of thin rubber. When you pull at the rubbers in turn you will see that the bricks are dislodged the same distance by different extensions of the rubbers. With the two bricks the extension is larger, and hence the applied force is larger, too.

Admittedly, there is nothing special here. Clearly, two bricks are
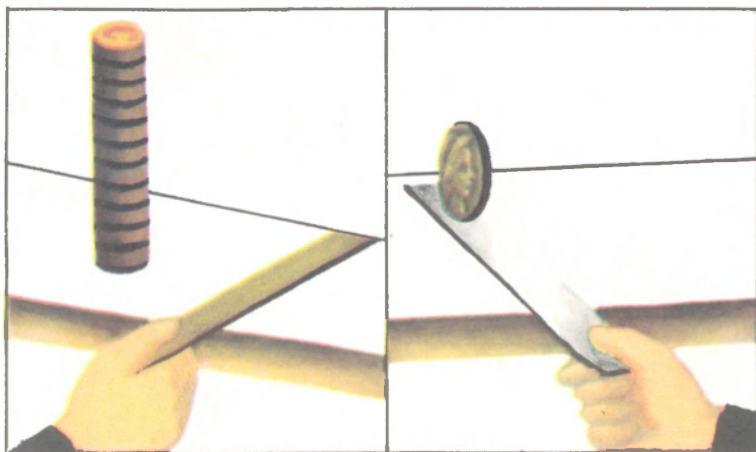
heavier than one, and to dislodge them requires more effort. What matters here, however, is not weight, but the fact that the two bricks have more inertia than the single one, and for the same acceleration to be imparted to them requires a larger force.

But the suspended bricks were not only displaced, but also raised a bit. Scientists say in such cases that the experiment is staged not correctly. Let's perform this experiment mentally: in an orbital station where everything is under no-gravity conditions. Our bricks are floating in mid-air, just as the objects often shown on television during transmissions from manned spaceships. Although the bricks now weigh nothing, the two bricks for the same acceleration will still require twice as much a force as the single brick. There is no weight, but mass did not vanish and inertia remained.

CHAINED-UP PLANETS. The powerful pull of the Earth retains on its surface everything that belongs here. Not only are people
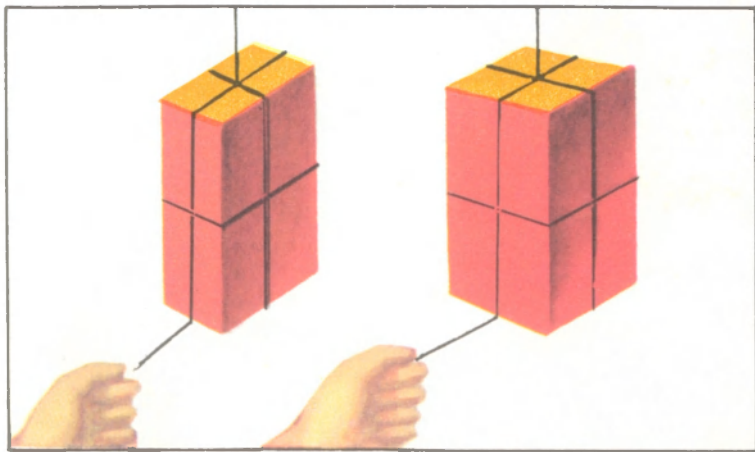
and living things retained here, but so are the stones, rocks, sands, water of the ocean, seas and rivers, and the atmosphere.

Isaac Newton formulated a very important law, the law of gravitation. He proved that gravity exists not only on the Earth, but in the boundless wastes of the Universe. All the bodies of the Universe — the Sun, planets with their satellites, stars, and constellations — are attracted by and to each other. The force of the attraction varies with the size of celestial bodies and the distances between them. The larger the distance, the weaker the attraction.

The Earth and the other companion planets of the Solar system, having been set in motion by some powerful force of nature, continue their motion in their respective constant, unchanged orbits.

Consider a stone spun around at the end of a rope. It cannot fly along a straight line, being retained in its circular orbit by the rope. But if the rope breaks or you let it go on purpose, the stone, seeking to move by inertia, will fly in a straight line that is called the tangent to the circular orbit.

Like the stone, each planet rotates on a "lead". Whereas with the stone the lead was the rope, with planets the lead is the powerful attraction of the Sun. The velocities with which the planets travel through space are enormous, and if it were not for the solar attraction pulling them from a straight path and making them move in elliptical orbits, not a single planet would stay with the Sun.

And the Earth in turn holds the Moon in its circular orbit with an invisible force and also makes it rotate about its axis.

But what would happen if the invisible "attraction ropes" were severed between the Earth and the Moon, the Sun and the planets? Suppose we switched off the attraction, just as we switch off a TV set, radio, or electric lamp?

The answer to this question comes from the following experiments.

EXPERIMENT WITH SWITCHED-OFF ATTRACTION. Before

we proceed to the main experiment, we will perform two auxiliary trials. The first one illustrates the case where a planet is stationary and is only subject to solar attraction. The second is where a planet moves in an orbit under attraction of the Sun.

Finally, in the major experiment gravity is "turned off" abruptly and inertia alone acts.

These experiments serve to demonstrate the great significance in nature of an interplay between seemingly conflicting phenomena.

The first experiment is very simple. Take a wooden or metal ball, or a round stone. It is at rest in your hand and you are standing on the floor. Now let the ball go and it drops on the floor. The experiment is over. Let's ponder the significance of the experiment. Imagine the ball that you held in your hand was a stationary planet, the floor on which you stand was the Sun, and the Earth's gravity acting on the ball was the Sun's attraction. It happens thus that a stationary "planet" attracted by the "Sun" falls to the latter.
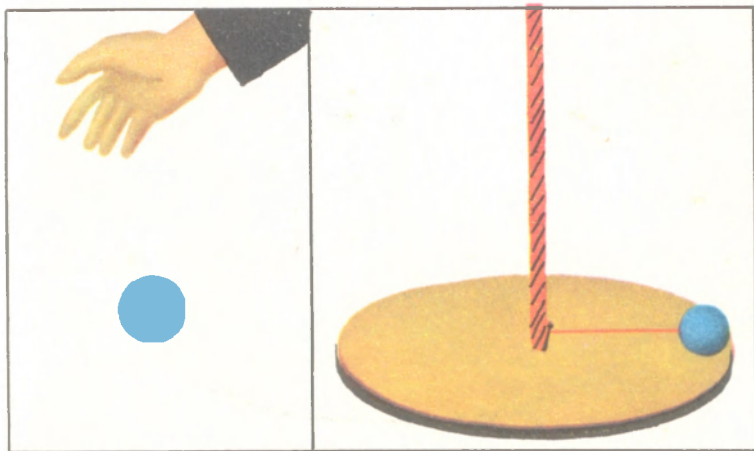
The second experiment is more complicated. First of all we will have to make a device that will also be necessary for other experiments.

Take a heavy circle 15-20 centimetres in diameter (e. g., the foundation of an old desk lamp or several rings from a cooking stove), slide through a hole at the centre two strong ropes 1-1.5 metres long and knot them. The circle should hang horizontally at this knot. If you have stove rings, you should cut from plywood two circles and clamp between them the assembled stove rings. The knot supporting the plywood circles should be tacked on small nails. It is necessary that the ropes cannot turn spontaneously in the hole as the discs are rotated.

Close to the central hole drive a small nail and tie a thin string to it. Pull the string to the edge of the circle and tie to its end a small metal ball or stone. The roles here are as follows: the ball is a planet, the centre of the disc is the Sun, the string is the solar attraction that keeps this "planet" in orbit. Make the disc rotate
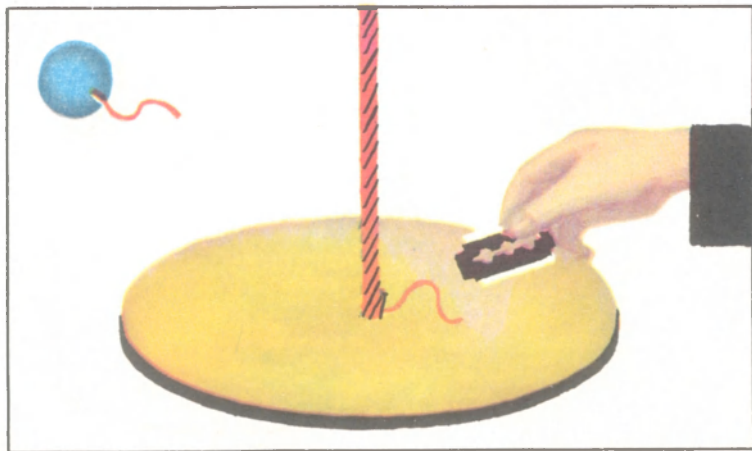
quickly. This will be a model of the motion of one of the planets round the Sun.

We now turn to the third, major experiment. When the disc has gathered speed, swiftly cut with a razor blade the string to which the ball, or stone, is tied, the closer the ball the better. This "switches off" the attraction of the planet to the Sun and the ball-planet flies by inertia in a straight line into "outer space", i.e., somewhere into the grass or bush. It is not recommended to do this experiment indoors lest you damage something. A simplified version of this experiment can be observed when knives are sharpened using a grinding wheel. A pencil of sparks flies off the wheel by inertia at a tangent to the rotating wheel. These are hot metal particles that cannot stay in the orbit where they are produced. No force attracts them to the centre of the wheel and the sparks are free to⁻ fly as they please, so they move in straight lines. Their motion being very fast, we do not see each spark separately but only their luminous tracks resembling the glowing tracks of meteors flying through a night sky.

EXPERIMENT WITH THREE BALLS. A force acting on a body makes it travel ever faster, i.e., accelerates it. It is common knowledge that acceleration varies with mass and applied force. The larger the mass, i.e., the bigger the inertness of a body, the larger the force needed to produce a desired acceleration.

In launching, a satellite or spaceship is accelerated to the required space velocity (if the spacecraft is to be launched into a near-earth orbit, then, as mentioned above, the circular velocity of about 7.9 kilometres per second is required). Once the desired velocity has been attained, engines are shut down and the vehicle travels by inertia at a uniform speed.

But a force can also be applied to a body during a very short time, e.g., in a push or kick. After this the body moves by inertia only.

We will now carry out some illustrative experiments.

Buy three similar rubber balls about 6 centimetres in diameter. Using a sharp pen-knife, cut a small slit no more than one centimetre in length in one of them. Into the slit insert a small funnel and fill the ball to capacity with dry, clean sand. Glue the slit flush with rubber cement. The cement will find its way into the slit if the ball is squeezed slightly.

Find a piece of not very strong, but sufficiently elastic, cardboard and cut out a strip 40 centimetres long and 4-5 centimetres wide. Puncture the middle of one end of the strip by a needle with a thread, tie the thread in a knot and, having bent the strip (see to it that it does not crack), put the thread through the other end of the strip and fasten it.

You will end up with a bow-like structure. But our bow is bent more severely and the ends are parallel to each other, then curving into an arch.

As for our experiment, put this cardboard spring on the smooth floor of a room, and on either side of it near the ends place similar
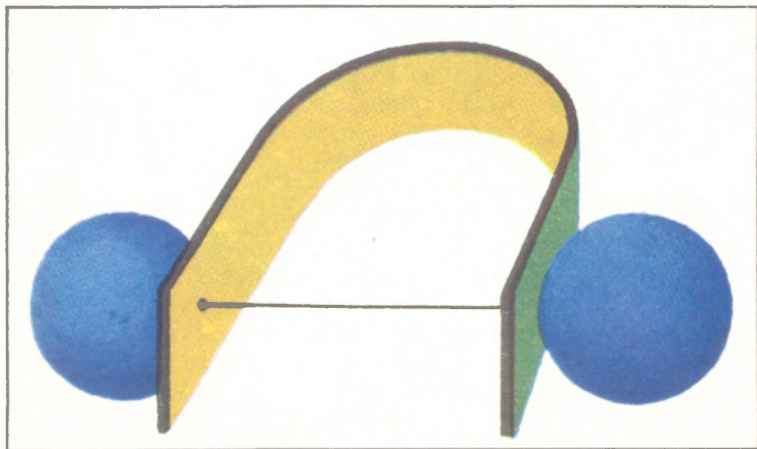
balls, putting them right up to the ends. Light a match and bring it under the midpoint of the thread. The thread will burn through immediately, the strip will straighten and kick each ball away with an equal force that only acts for a very short time. The balls will roll away in opposite directions to an equal distance.

After this experiment load your cardboard spring again in the same way. Again place it on the floor, at the same place, but now use dissimilar balls: on one side, a conventional ball, on the other, a filled ball. Check that the balls touch the strip as before and burn the thread. The cardboard spring straightens again, pushing the balls in the opposite directions. The balls roll aside, but now to different distances. The filled ball has a larger mass, therefore it will travel a shorter distance.

In these experiments handle fire with caution. Of course, the thread can also be severed using scissors, but this may produce an additional push that through the strip will be transferred to the balls, which is to be avoided.

FROM BALLS TO A ROCKET. You have just performed experiments to illustrate a very important law that lies at the foundation of the launching of artificial satellites, spacecraft, and rockets. This is the law of conservation of momentum.

All textbooks on physics have a section called "Mechanics", which contains the notion of the *momentum* that is graphically derived from Newton's second law of motion.

Symbolically, the notion is mv. In words, it is the product of the mass of a body, m, by the velocity, v.

When experimenting with similar balls, i.e., ones with equal masses, we saw that when subjected to the same force the balls rolled through the same distance, thus suggesting that their initial velocities were equal. If we multiply the velocities of the balls by their masses, we will obtain equal products. The only distinction was the opposite directions of motion.

In the other experiment, with different masses, we also arrived at

the same product of masses and velocities. For one ball the mass was larger but the velocity smaller, and for the other the mass was smaller but the velocity higher.

When forces act in a closed system (and our balls and the spring can be viewed as such, ignoring the friction with the floor and air) then the law of the conservation of momentum works.

A starting rocket, too, is a closed system. It will move by using its internal reserves. Nobody is pushing it from the outside and when it is about to start, its momentum is zero. But when its jet engines fire, very hot gases shoot out of the nozzles at enormous speed and the rocket sours up.

If we multiply the total mass of these gases by their velocity, then the product will exactly equal the product of the mass of the rocket's body by its velocity. Only the directions will be opposite: the hot gases strike in the direction of the Earth whilst the rocket flies away from the Earth.

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REACTIVE FLOAT. We begin with an experiment that will enable us to observe reaction motion, so to speak, in nature. The experiment is rather simple but for the best results it must be well prepared.

Cut out a rectangular piece of wood 1.5 centimetres thick, 5 centimetres wide and 10 centimetres long. This is to be a small float and the key element of our rig. At the middle of an end face glue a halved bottle cork, as shown, using a cement insoluble in water, and then fasten it with a small nail. One end of this half-cork must be flush with the board, and the other should protrude by about 2 centimetres. Next cut two narrow strips (0.5 × 10 cm) from cardboard and glue them along the length of the float from the cork, as shown, 5 millimetres apart.

Experiments with Reaction Motion

Bend a razor blade (have several at hand, just in case) as far as it will go and tie the ends with a string in the same way as you did when you "charged" the cardboard spring in the ball experiment. The blade here is going to be the spring. Turn the bent blade "ends up" and attach one end to the cork with a string. In addition, press the end to the cork fast with a thin wire.

For this experiment we will also need a wooden or plastic ball about 3 centimetres in diameter. The ball must weigh not more than 10 grammes. A wooden ball has the advantage that it will float and will be much easier to find if the experiment is performed on a pond or lake. Admittedly, the experiment can also be performed well in a large pan or bath. The basic requirement is that water is still and there are neither waves, nor currents, nor wind.
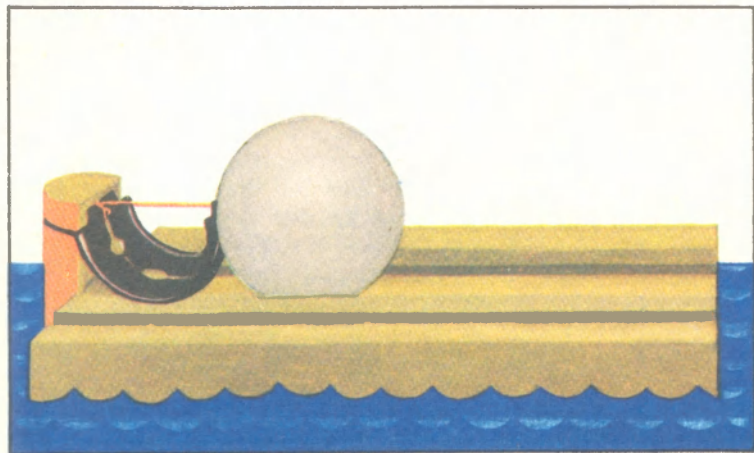
Place the float with the "charged" spring-blade on water. Place the wooden ball on the cardboard track, placing the ball flush with the blade end. The latter should touch the ball at the middle or a bit higher. Once the float has settled and ceased rocking, put

a burning match under the string. See to it that the match does not actually touch the string or blade. The string will burn and the end of the blade will strike the ball so hard that the latter runs down into the water, our float moving in the opposite direction.

Remember the experiment with a cardboard spring striking two balls to send them in the opposite directions. Here we have the same thing only the second ball is the float itself. In both cases the principle of reaction motion was responsible.

The ball that ran down from the float can be likened to the fuel combustion products shooting out from rocket nozzles. On straightening, the spring pushed the ball and also the "wall of the combustion chamber" – the cork – to which it was fastened. As a result, the ball was thrown out of our floating "rocket", and pressure on the opposite wall of the "combustion chamber" made it recoil in the opposite direction.

In a starting spececraft fuel burns continuously during a short period of time. From a narrow, ever expanding opening – the noz-

zle – combustion products (gases) are ejected at high pressure and
with great velocity.

A spacecraft can travel through empty space with its engines run-
ning. In order that fuel may be burned in the combustion chamber
a required amount of oxygen is supplied. And the craft only travels
due to reaction propulsion, i.e., recoil force, and not due to push-
ing off from air.

Recoil also occurs in firing a cannon, a gun, or a rifle. The shell
or bullet flies in one direction and the cannon or rifle kicks, in the
opposite. But the mass of the shell or bullet is much smaller than
that of the cannon or rifle. Remember the experiment with the
balls of unlike masses. Which of them rolled off the farther? The
one with the smaller mass, of course.

IT ALL STARTED WITH A TOY. Strange as it might seem, the
reaction propulsion now widely used in aviation and space flights
has been known since ancient times, but it found no application,
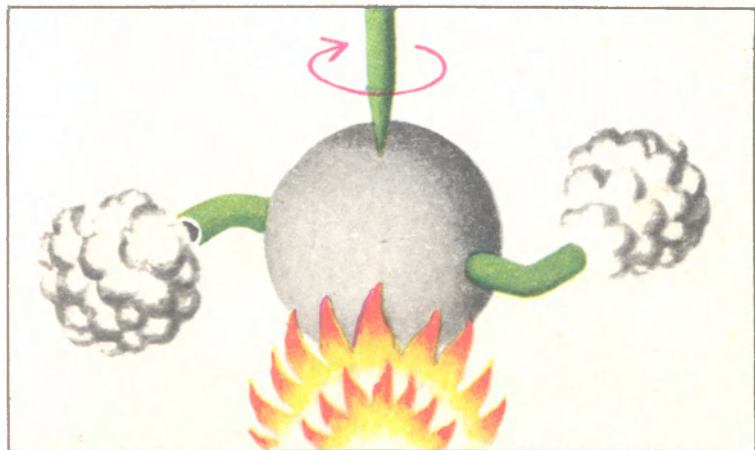
save in attractions. Descriptions are available of a steam aeolipile
that rotated owing to escaping steam jets. Its construction was
quite simple. Into a ball-shaped boiler, water was poured; the
boiler was placed on a fire, the water boiled and steam burst out of
two tubes bent clockwise (or counterclockwise). The boiler was free
to rotate on two vertical axes and at the tube bends a reactive force
was engendered with the result that the boiler began to rotate
quickly. But in those early days it never occurred to anybody that
reaction motion would enable man to send ships to the Moon,
Mars, Jupiter, Venus, Mercury, and the other planets of the solar
system.

The first to reveal the possibility of using reaction propulsion, if
only as the above amuzement, was the Greek geometrician and in-
ventor Hero of Alexandria (fl. AD 60). And in 1750 the Hungarian
physicist and mathematician Johann Andreas von Segner developed
a device based on the reaction motion produced by escaping water
jets. The device is known as the Segner wheel and now it is an in-
fallible piece of demonstration apparatus in any school physics
room.

When gunpowder came in, it was used for toy rockets and a va-
riety of fireworks. Toy rockets began to be employed as a signalling
means in warfare, and in the 19th century rockets started to be uti-
lized as a weapon.

And it is only then that the idea originated that rockets, much
more powerful of course, might be used for space travel. The revo-
lutionary, member of Narodnaya Volya, Nikolay Ivanovich Kibal-
chich, imprisoned and sentenced to death, several days before his
execution sketched the first design of a rocket airplane for manned
flights.

But the complete scientific foundation of manned space flights is
due to Konstantin Eduardovich Tsiolkovsky. He is the father of
the science of interplanetary travel. So he made important contri-
butions to the theory of space vehicle design, fuel design, and calcu-
lated the required velocities and trajectories.

Now the aerospace technology is well advanced and we see frequent space flights for scientific purposes. Progressive men struggle for space technology to be only used for scientific aims, for the benefit of man. The possibility should be excluded of its being utilized to destroy people and all that has been created by people.

These days hundreds of artificial satellites are carrying out enormous work studying terrestrial space. In addition, they enable TV programmes to be transmitted, telephone and telegraph communication over great distances to be achieved and they warn about weather changes and coming typhoons. Worth especial mention are the Soviet and US space flights to the Moon and other planets of the solar system. Sometimes satellites are orbiting around the Moon, Mars, and Venus transmitting a sea of valuable scientific data.

Reactive propulsion is applied not only in space. Present-day aviation relies mostly on jet propulsion. This is more cost-effective, faster and safer.

Could Hero of Alexandria as much as dream of it when he first marvelled at his rotating reactive toy? Even the physicist Segner, demonstrating his now-famous wheel, seems not to have attached much importance to this device and reaction motion on which it relied.

EXPERIMENTS WITH AEOLIPILES. The next experiments will help us to reproduce the historical toy of Hero of Alexandria and the physical device of Segner.

To begin with, we make a model of a rotating ball. But our ball will be driven not by steam but by air. However, its principle of working will be the same – reaction.

Take a ping-pong ball and several drinking straws. The length of the straws is immaterial as we will cut them into pieces. Wash the straws and cut two 8-cm lengths bending them nearly into a ring. Don't try to get a closed ring, just bend them until the inner surface crumples. Tie the ends with a string and leave the rings for

a time for them to "remember" this configuration.

Make three small holes in the ball for the straws to fit in tightly. If one hole is a pole, the other two are on the opposite sides of the "equator". Into the "polar" hole insert a long rod and seal up the periphery of the hole with Plasticine. Insert the bent tubes into the holes of the "equator". These can be pushed into the ball up to half their length. Of importance here is that the outer ends are slanted into the plane of the equator, and end up almost parallel to the surface of the ball and directed in one direction. These connections must be sealed with Plasticine, too. Take a paper strip about 5 centimetres wide, roll it into a thin tube, glue the end and slide it onto the long straw. Put the ball on a smooth surface, holding the paper tube with the straw inside vertically, as shown. Now blow into the long straw. The paper tube, which you hold in your hand, will act as a "bearing", and the surface of a table, a "step bearing". The ball will rotate in the opposite direction to that in which the small tubes are facing.
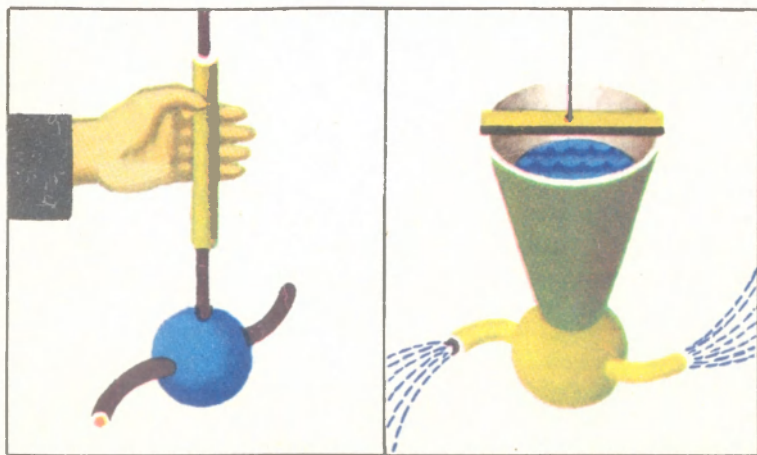
The device can be improved. Pass the long straw all the way through the ball (through its "south pole") and into the lower end insert the end of a ball-point pen. In the part of the tube that is inside the ball punch several holes to let the air into the ball. Install the device on a small support with wire bearings and a recess in a board for step bearing. This will make rotation more stable.

The other historical device, the Segner wheel, can be made as follows. Glue together a cone of strong paper or thin cardboard. Along the diameter of the cone base fix a wooden lath and drill a hole in the centre of the lath. Cover the inside and outside of the cone with a drying oil, then paint with oil paint and, after it has dried, cover with varnish. All this is required for the cone not to soak through when we pour water inside it. Pass a piece of string through the hole in the lath, tie a knot and suspend the cone, apex down, over a place where you can experiment with water. Make a hole in the apex (it is now below) and fix to it the ping-pong ball of the model just discussed, as shown. Do this by cutting a larger hole at the "north pole" of the ball and insert the apex into it. Paste the connection with a glue that cements celluloid (e.g., nitrocellulose glue). Next, prepare short, narrow pieces of paper and glue them so that one end is fixed to the ball and the other to the cone. Besides, above these strips glue longer narrow strips along the two connections so that the one side of the strip is glued to the ball and the other to the cone. The strips may overlap. For added strength, the connection should be wound with string in several layers, gluing each layer completely. Now pour water into the cone. It may be that to overcome the friction and inertia of the cone you will have to turn it slightly in the direction opposite to that of water jets.

We do not indicate dimensions here, but it may be that under the pressure of water the ball will be torn from the cone. In this case take a length of wire 0.5 millimetre in diameter and pass it through the hole in the lath and through the "south pole" of the ball, seeing to it that this place does not leak. Pass the end of the

wire through a small metal washer and tie it to a wooden stick or
a nail. Seal the "south pole" with a patch cut from another ball.
For the copper wire from which the device is suspended not to
twist, make a small hinge with a loop to receive the wire at the
place of suspension. You could, of course, do without the hinge by
binding the end of the wire to a thin string. What is required is
that the wire itself does not twist.

Nowadays the Segner wheel has ceased to be a toy only. It is
generally used to water plants. The reaction of a water jet rotates
the head with the water sprinklers. The gardener need only transfer
this light-weight rig and hose to another location.

JET BALLOON. The next experiment concludes the series of
experiments on rotation based on reaction motion. Take a balloon
and inflate it to capacity. Just before you tie the opening with
a string insert into it a slanted drinking straw. Initially melt the
outer end of the straw with a match to close it.
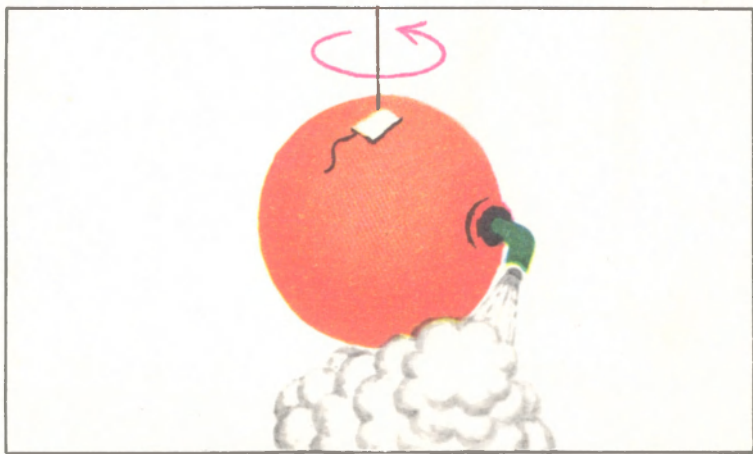
On the side of the balloon fix a string using cellotape. When you suspend the balloon the tube should be on the equator. Check that the tube bend lies in the horizontal plane. When the balloon has stopped swinging, cut away the end of the tube. The air will begin to escape from the balloon through the straw and the latter will rotate.

This experiment can also be performed without suspending the balloon. You need only place it on water in a small pan and it will spin. The diameter of the pan should be smaller than that of the balloon.

REACTION SHOWER. If your bath is equipped with a hand shower with a flexible hose, you can stage a fascinating experiment.

Suspend the shower head from the hose vertically above the bath. It will hang vertically because the shower head with the handle are heavy enough. The head is subject to no force except for gravity. But once water has been turned on, the head moves in the
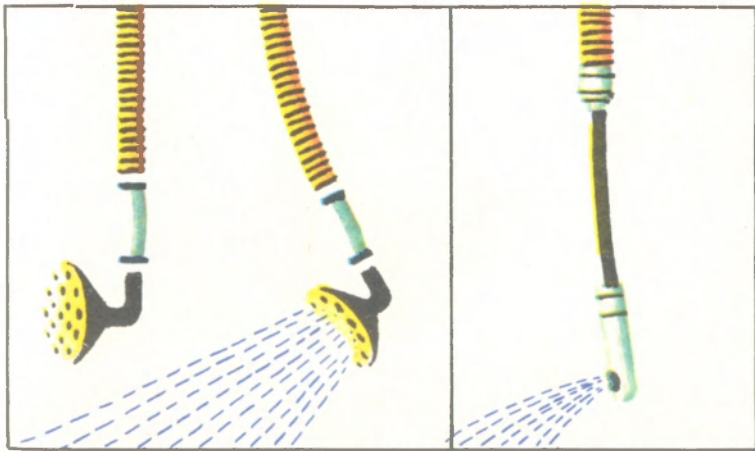
opposite direction to the jet. Where the water turns to come out of the holes in the head a reaction force is generated, which is responsible for the movement of the head from the vertical.

If such a shower is not available, the experiment can be done in another way. Suspend the plastic body of an old ball-point pen from a thin rubber tube. Into the larger opening insert a tube, and close the smaller opening with a wooden stopper. Drill a hole in the side of the body.

If you allow water to flow through the tube, the water, shooting out as a jet from the drilled hole, will exert a reaction force on the opposite wall of the plastic. This force will deflect the rubber tube from the vertical, i.e., we will witness the same thing as in the case of the shower. Again the reaction of the jet.

To have an adequate head of water, you can (instead of the domestic water supply) use a vessel with water positioned at a high level. Insert the free end of a long tube into the vessel down to the bottom, and from the other end suck water with mouth. When the water starts flowing, it will do so as long as the upper end stays in water. The device is called a siphon.

JET SHIP. This is not a spaceship, but a toy floating in water. It is fuelled by an unusual "fuel", or shall we say power source, by carbon dioxide.

Take a round plastic box, e.g., a processed cheese container. The only requirement is that the container and its cover is undamaged and the cover fits tightly. For best results smear the periphery of the cover with Plasticine. If you add some water into the box and turn it upside down, water must not leak. Just under the cover, in the side of the box, make a small hole with a red-hot nail.

For the experiment you will require several pieces of dry ice with a total volume of a chicken egg.

Onto the bottom of the box, place the cover of a mayonnaise jar cover. It should occupy the whole of the box bottom. Spread it uniformly with several pieces of dry ice, add some boiling water and

quickly cover the box and place it on water. The carbon dioxide, evaporating violently, will escape from the hole in a jet with the result that the box will float in the opposite direction.

It is a good idea to rehearse the experiment with pieces of chalk instead of dry ice to assess the amount of boiling water to be added into the box, as the box must not capsize and the hole must be above water.

IMPULSE SHIP. You may know that a spacecraft accelerates gradually in launching. Its engines are arranged in stages to build up speed over a substantial acceleration run. The gradual speed build-up, or gradual acceleration, is required so as not to damage the health of astronauts or the equipment (in the case of an automatic station).

Recall the heroes of Jules Verne's novel *From the Earth to the Moon* who set out to their space journey on a cannon ball. At the instant they left the barrel of a huge cannon the velocity was
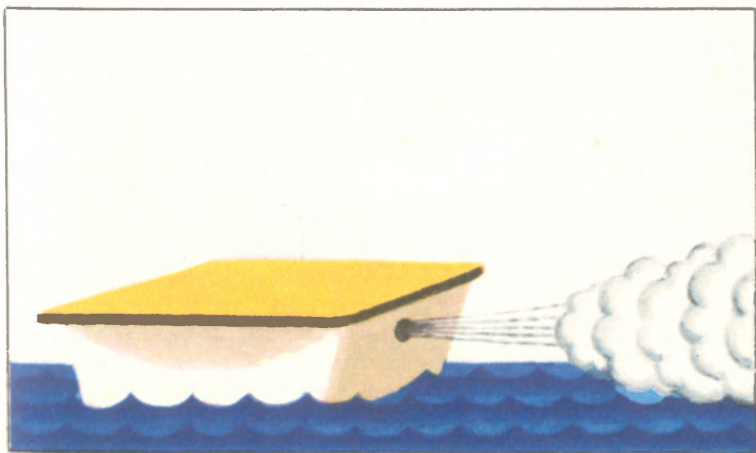
16 kilometres per second, but the acceleration occurred along the cannon barrel only 210 metres long. The well-known popular-science author Ya. I. Perelman has worked out that the crew of the ship would not have survived accelerating from 0 to 16 kilometres per second over such a short run. Of course, we usually tolerate a measure of exaggeration in science fiction, otherwise it would be impossible to produce a piece of science fiction. But reality, at times, surpasses fantasies. Jules Verne's heroes have only flown round the Moon, but our contemporaries, the American astronauts, have visited it. True, they did not travel on a ball or from a cannon, but in a spacecraft that could ensure their safe launching both from the Earth and from the Moon.

There was once a fascinating toy, an impulse boat. It moved in jerks and starts, the jerks followed one another, the boat travelled ever faster until the water resistance and the motive force equalized each other, thereafter the boat continued moving at a constant speed.

What was its principle? The boat was of metal, about 12 centimetres in length. A small flat brass boiler was installed at the aft with a brass tube going from the boiler astern. When the boat was afloat the end of the tube was under water. Initially some water was added through the tube into the boiler with a pipette, then a piece of cotton wool was placed under the boiler and set on fire; the boat was put on water. The water in the boiler came to the boil and, together with steam, escaped as a jet into water through the tube. This gave a reactive push, and the boat moved ahead. But after this exhaust a vacuum formed inside the boiler and outside water immediately refilled the boiler. Since the fire was still burning and the boiler was hot enough, the fresh dose of water boiled quickly and shot out of the tube. A fresh push, a fresh tot of water inside, and so on, as long as the fire kept burning.

The toy is extremely interesting and it resembles a multistage rocket. Were it not for the resistance of water, it would accelerate to a great velocity.

We will now manufacture a simplified model of this boat. Take
the thick metal ink reservoir of a ball-point pen. Remove the plas-
tic plug from its end using pliers and pull out the small tube with
the ball-point. The remains of the ink should be removed with
a piece of cotton wool soaked in alcohol or eau-de-Cologne. From
the thick end of the reservoir cut off a 3 centimetre piece using
a small hack saw or a file, and squeeze the thick end of the remain-
ing part with pliers. Seal the end by bending over a 3-mm edge and
squeezing it with pliers, then repeat this operation.

You will end up with a tube 5 centimetres long, sealed at the
thick end, and its narrow end having a length of 1.8 centimetres.

Take the lid of an old tea or coffee tin can. At some place
straighten a bit its edge and punch a hole so that it will tightly
receive the thin end of the prepared ink reservoir. If its fit is not
sufficiently tight, it must be secured in an inclined position with
a piece of thin wire for it to sit rigidly in the hole.

When the lid floats, the thin end of the tube must be below the

surface of the water. Pour water into the "boiler" and put under it a piece of cotton wool soaked in kerosene. Kerosene liberates a great deal of smoke in burning, therefore the experiments should only be performed outdoors.

Pour the water in thus: select a pipette whose end fits into the narrow end of the tube, fill the pipette with water and inject the water into the tube forcefully. There is also another way of filling the "boiler": heat it up with a burning match and put in water at once. The heated air inside will cool down, its volume will decrease and water will enter the "boiler".

Our "navigation" will require a large pan or bath. When the flame of the cotton wool heats the "boiler", the water inside it will come to the boil and our "ship" will begin to move. It will travel in a circle because the tube dipped in water will be sort of a rudder (an oar held in water to turn a boat). Further, the exhaust tube is sure to be off-centre. All these factors will combine to make our ship travel in a circle. The frequency of bursts will not be very high, but quite enough to propell the "ship". And it will move as long as the fire is burning.

CONTROLLED MICROROCKET. In this section we will deal with small models of space vehicles. They will travel over the surface of water and their motion will be due to a reaction force.

Onto the surface of water in a pan place a microrocket cut out of strong paper. At the front end it should be pointed and at its tail a small canal must be cut out so that it has a "combustion chamber" in the front (see the accompanying figure). The chamber's diameter should be twice the width of the canal. At the outlet, the canal should gradually fan out (a triangle-shaped cut) to form a nozzle.

Now take a pipette, using soapy water such as that used to blow soap-bubbles (prepared beforehand in a saucepan), and place a drop into the "combustion chamber". Soapy water has the property that it spreads quickly over the surface of clean water. So it

will flow out of the canal, through the nozzle and will, thereby, exert a force on the opposite wall of the "combustion chamber". The rocket will move forward.

Let us make a controlled microrocket. Cut out a wider rocket to obtain two "combustion chambers" as shown. If we add a drop of soapy water into the right "combustion chamber", our rocket will move to the left; if into the left, the rocket moves to the right; and if into the two simultaneously, it will move forward.

Unfortunately, the water will soon be covered with a soapy film, and the rocket will cease to respond to fresh drops of soapy water. Therefore after each run the water in the pan should be changed.

Rockets can also be made of metal, e.g., out of a razor blade. Place a blade on a board, press a knife along the middle and break the blade, having wrapped the free end with paper to protect your fingers. Carefully place the half-blade onto the water. It will float. Add a drop of soapy water into the round hole in the blade and the blade will move forward.
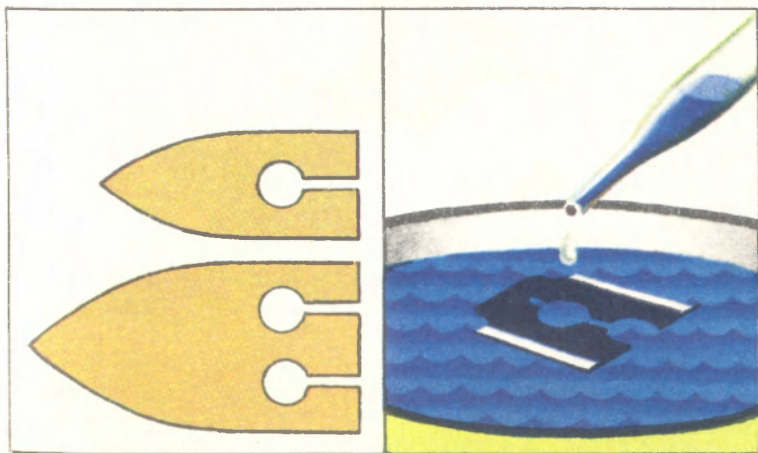
HYDROPNEUMATIC ROCKET. This rocket was developed by
the engineer Yu.A. Moralevich and it was once very popular with
children. It combines simplicity of construction, excellent flight per-
formance, and complete safety.

This rocket (which we are going to manufacture now) can reach
a height of 20-25 metres. Try to work accurately on the rocket so it
can be used several times, to everybody's delight.

What materials are we going to need? Prepare them beforehand
for them to be at hand.

Thus, we will need the following:

1. Several old nylon stockings.
2. A cotton reel.
3. Three bottle nipples.
4. Several pieces of thin plywood (1-1.5 mm thick).
5. Water-resistant glue. (This can be prepared by dissolving frag-
ments of celluloid toys, combs and photographic film, cleared of
emulsion and dried in acetone or amyl acetate.)
6. Football pump.

In addition to these main materials you should have at hand
a wooden stick or a bar to make the dummy on which the rocket is
formed, threads, a rubber tube, plastic foam, sawdust, enamel
paints and some other supplies that will be mentioned in the de-
scription of the manufacturing process.

Now to the work. Out of a round stick or a wooden bar cut
a streamlined dummy. For it to be absolutely symmetrical make
a template by bending a piece of cardboard in two, and drawing
the half-profile of the rocket on it. Now unfold the cardboard, and
you will get the complete profile. Use the template to check the
symmetry of the shape being manufactured.

The dummy is first shaped with a knife, then with sand paper to
get smooth surface. Now wrap the dummy in two layers of wet
paper. When the paper has dried, wrap the dummy with a ribbon
5 centimetres wide cut, in a spiral, out of a nylon stocking.

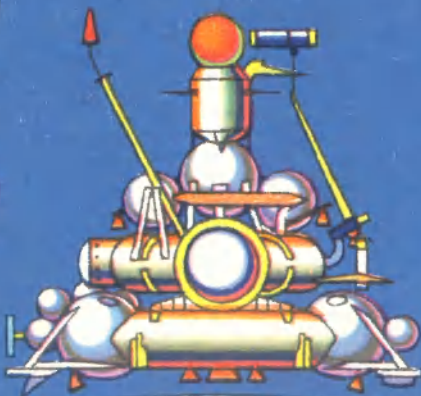Each turn must be smeared with the stiff glue mentioned above.

Lunar probe "Luna 1"
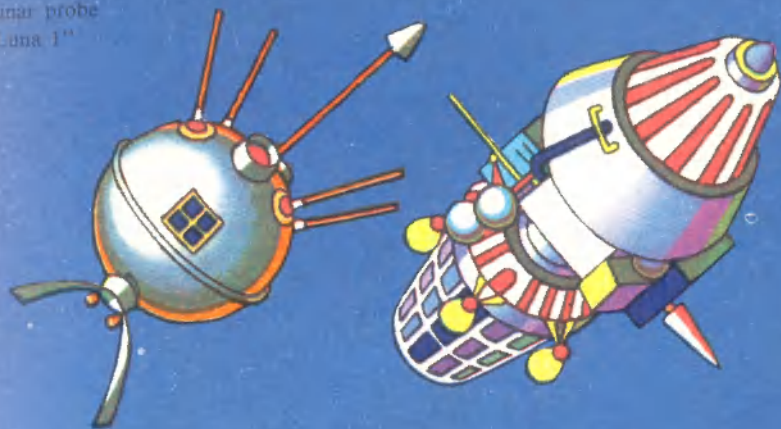
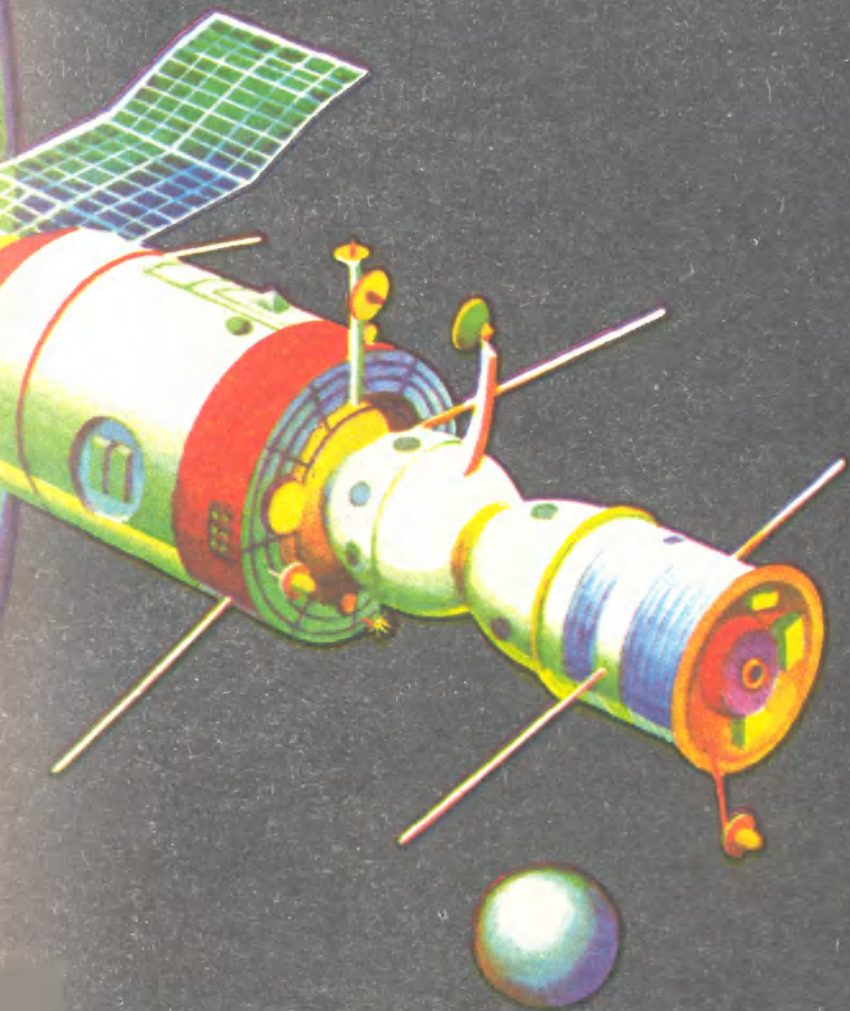Lunar probes "Luna 2" "Luna 9" and "Luna 24" took these insignia to the Moon

Lunar probe "Luna 16" brought first samples of lunar soil to Earth

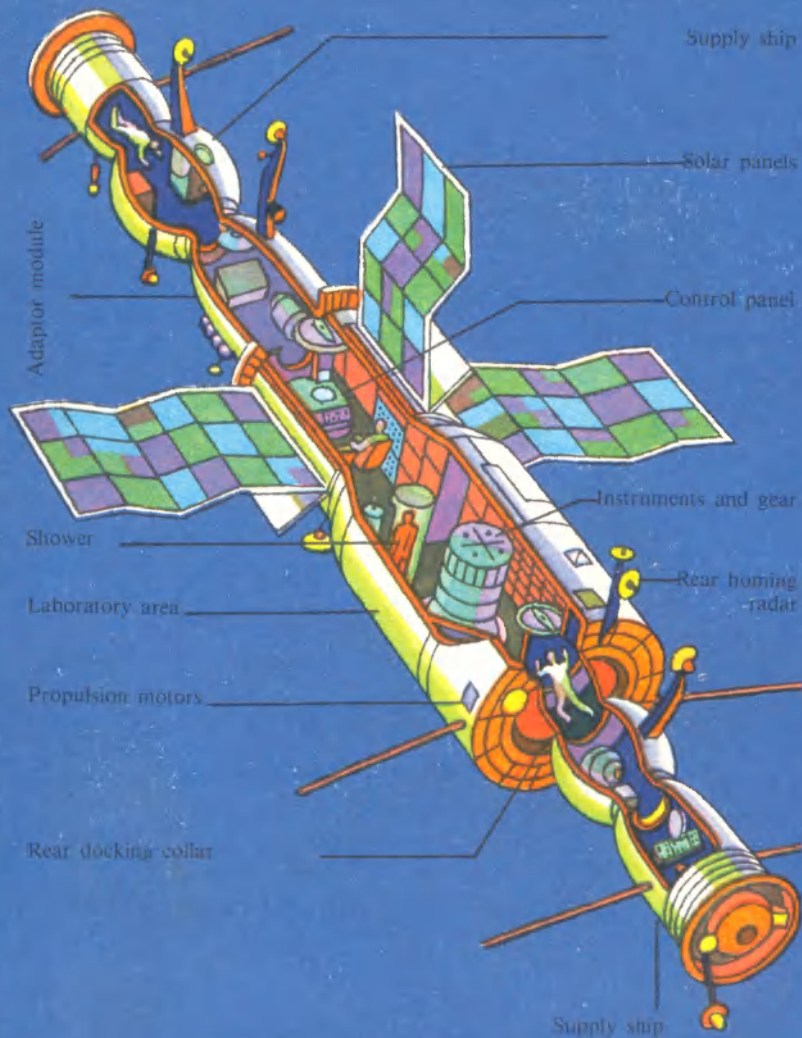Automatic station "Luna 16", an artificial satellite of the Moon

Supply ship

Solar panels

Adaptor module

Control panel

Instruments and gear

Shower

Rear homing radar

Laboratory area

Propulsion motors

Rear docking collar

Supply ship

The complete "Salyut 6" complex

Once the first layer has dried and a glossy film has appeared, you
can proceed to wind a second layer. When it has completely dried,
wind other layers. You should end up with a solid nylon envelope
up to 1 millimetre thick. Special care should be exercised in gluing
the upper, blunt end of the rocket. After gluing the nylon, make
a casing of thread that is wound along the upper edge of the rocket
and pasted with the same glue.

Before covering with the ribbon, fix a cotton reel into a recess in
the bottom of the dummy. The reel should be prepared as follows:
cut one edge with a knife, and then insert a rubber tube into the
canal bending the end of the rubber around the cut. If the tube
cannot be bent, fasten it with a piece of copper or steel tube. This
prevents the rubber tube from dislodging.

Now the reel is securely fixed to the rocket body and constitutes
the nozzle of our rocket. It does not fan, however, as a real nozzle
should, nevertheless it serves its purpose adequately.

After the body has dried sprinkle it with a mixture of talc and
glue, and sand it down lightly to smooth.

To the bottom of the rocket glue three tailplanes cut out of thin
plywood, utilizing the stiff glue used earlier to cover the rocket
with a nylon ribbon. Paste the connections of the tailplanes and the
body with a mixture of fine sawdust and the stiff glue. This will fix
the tailplanes securely.

Lastly, paint the rocket and tailplanes with an enamel paint or
conventional oil paint.

Having dried the rocket to perfection cut its body in the middle
with a sharp knife and carefully take the halves down from the
dummy.

Remove the paper used to cover the dummy from the insides of
the halves, though some of the paper may be left stuck to the nylon
ribbon. Bring the halves together and glue them together with
a nylon strip. Repaint the rocket.

Put one bottle nipple into another and pump the inner one with
a pump. Tie the inner nipple securely. This will make a good shock

Dummy template

Rocket nose

Dummy gluing

General view

Tailplane 3 pcs

Rocket tail
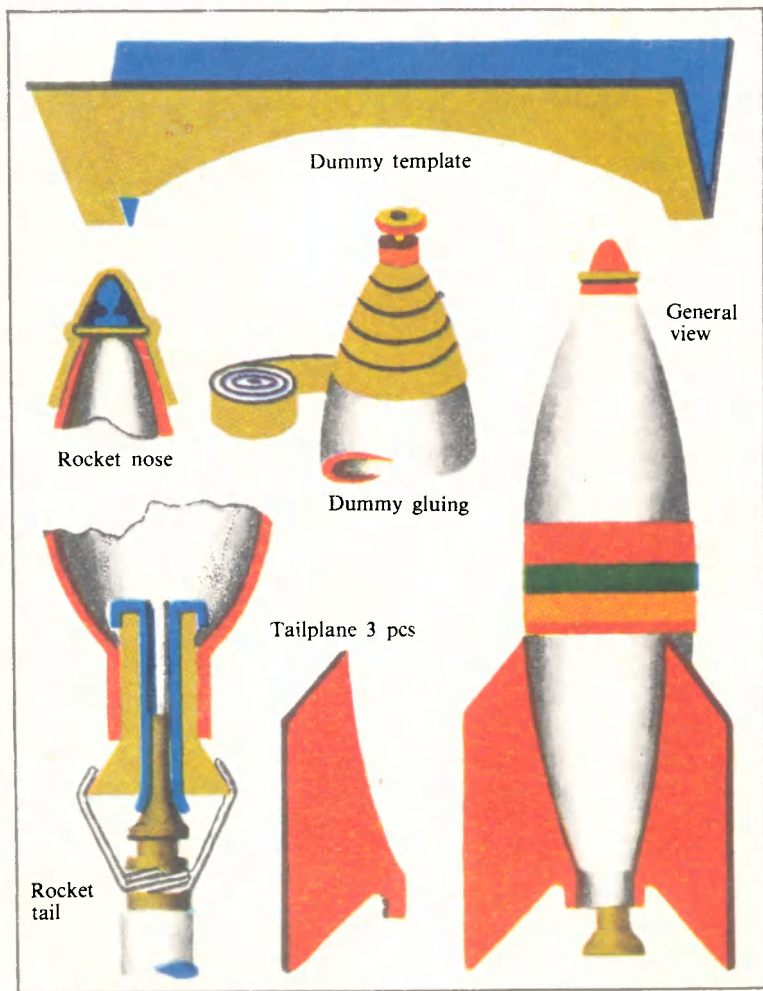
absorber to protect the rocket in landing. Slide the upper nipple with a "reservoir" of compressed air inside on the end of the rocket where we have provided a thread fillet, and tie it with a thread for the shock absorber not to come off the nose.

Alternatively, the inner nipple need not be pumped up but supplied with a piece of plastic foam.

We will now have to prepare the pump. On its tip grind down the first ridge for the tip to fit into the reel hole. Make two trigger tongues of resilient wire and tie them to the lower ring ridge on the tip.

Pour some water into the rocket until it is one-third full. Insert into the reel-nozzle the pump tip, clamp the reel sides with the trigger tongues and hold them with your hand. Pump about 30 strokes. Unclench your fingers, the tongues will loosen and the rocket will fly off. The air throws the water out creating a powerful jet, and the reaction force pushes the rocket up. After the first launching watch the rocket falling. If it falls nose down, everything is in order. Otherwise, you will need to add some weight to the nose by gluing several more layers of nylon ribbon. Obviously, the talcing and painting operations must be repeated.

AROUND ITS AXIS. As they revolve around the Sun, all the planets rotate around their respective axes as well.

Our natural satellite, the Moon, in revolving about the Earth, always shows us only one side. So in one turn about the Earth the Moon makes one turn about the lunar axis.

We will produce the following experiment. On a sheet of paper draw a circle 20 centimetres in diameter and, at its centre, draw a small circle. It will be our Earth. A ping-pong ball will be our Moon. Pierce the ball with a needle and fix a string to it. Using India ink paint the half of the ball with the string and place it on the circle just drawn. As you have already guessed, the large circle will be our Moon's orbit. Turn the ball to face the Earth with its light side, and tighten the string tangentialy to the ball.
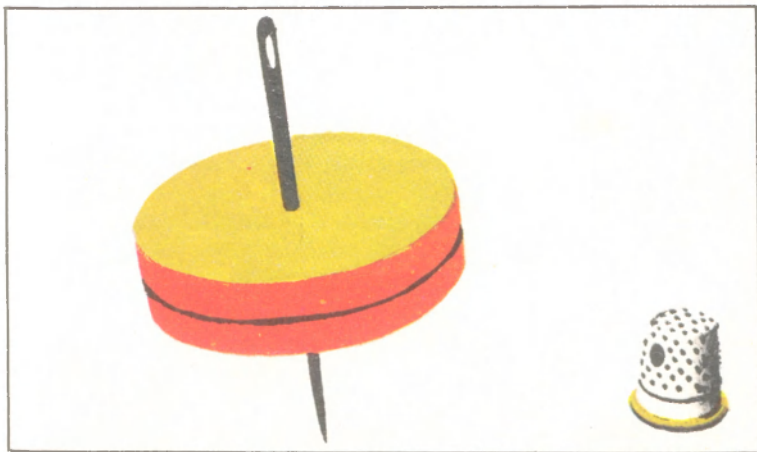
Planet Earth,
the Cosmic Top
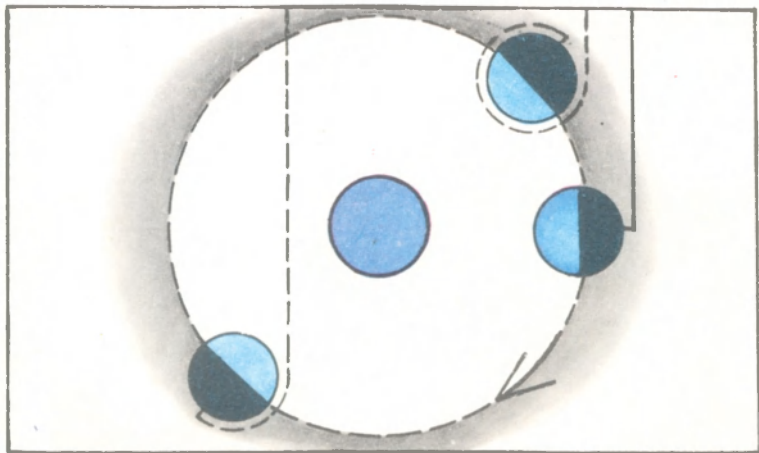
Now start moving our Moon in orbit turning it with its light side to the Earth (as shown). The string should be taut pointing in the same direction during the entire procedure, thus gradually winding onto the ball. In one turn in the orbit the string will have wound onto the ball once. This implies that the ball, in one turn of its orbit, with one side always facing the centre, also made one turn about its axis.

WE LIVE ON A TOP. The Earth is a tremendous top, as it rotates about its axis. But the axis of any top has an amazing stability, seeking to retain its direction in space. And if an external force makes the top turn, its axis always turns in the direction perpendicular to that of the force.

Make this well-known experiment with a revolving bicycle wheel. Hold the wheel in both hands horizontally and ask somebody to rotate it as fast as possible. Now try to turn the axis into the verti-

cal position, and you will see that this is very difficult.

Let's make a simple gyroscope that will be able to spin for a long time. Take a needle 10-12 centimetres long and a tin can used for cinefilm. Punch a hole through the centre of the can and insert the needle so that its ends protrude on either side by the same length. Having cleaned the bottom of paint, solder the connection of the can with the needle thoroughly.

Drill a 5-mm dia hole in the side of a metal thimble and insert a string into the needle's eye winding it several times around the needle. Pass the loose end of the string into the thimble and through the hole. Place the tip of the needle onto a hard, but not slippery, surface and put the thimble over the needle, pressing it slightly with your left hand. Pull the string with your right hand. Once the top has been launched, remove the thimble and watch the spinning of the top. It will spin for a long time on its tip. The friction at the support here is negligible, but the air friction will be more of a problem.

It is next to impossible to start the top with its axis strictly vertical. Push the axis over slightly. And, although, as has been said above, the axis of a spinning top seeks to retain its direction in space, terrestrial gravity seeks to topple the top over owing to the displacement of the centre of mass from the vertical. In the process, the top of the axis begins to describe a circle. This motion of the axis about the vertical line that passes through the support of the top is called precession.

If for some reason or other, you cannot manufacture the top as described above, make a simplified version of it. Cut a 5-cm dia ring from cardboard, punch a hole with a nail, insert a match with a sharpened end, and the top is ready. Now it will not spin long, but still you can observe precession with it.

Returning to our discussion of the Earth, the terrestrial axis, or rather the invisible geometrical line about which the globe revolves, precesses, too. The upper "half" of the Earth's axis circumscribes a cone whose apex lies at the centre of the Earth. The lower one

circumscribes a cone also with the apex at the centre. Actually, the Earth's axis circumscribes two axially symmetrical cones with a common apex.

The axis of a top spinning on a table precesses owing to terrestrial attraction seeking to topple the top. Well and good. But what causes the Earth's axis to precess? The Earth is travelling free in space! The Sun holds it fast in its orbit. It might be expected that any globe revolving about the Sun should have all of its points uniformly attracted to that powerful luminary as a globe is almost symmetrical about all of its axes. Then, where does this precession of the Earth come from? It turns out that the Earth has a cause for the precession and its discovery is due to Isaac Newton.

To get to know the cause, carry out the following experiment, We will observe the behaviour of a fast-rotating body whose surface can easily change its configuration. We will here make use of the device manufactured to observe fast rotation, viz., a heavy disc clamped between two plywood discs and suspended at the middle from two twisted ropes.

Cut a 60×2.5 cm strip from drawing paper. Glue its ends together to form a ring with a diameter of about 18 centimetres Make two holes in the middle of the strip at the opposite ends of the diameter. Through these holes, twisted ropes will pass that support the disc. One of the holes should be where the strip was glued together. The second hole in the strip should be a bit larger for the rope to slide freely in it. Pass the rope through the holes so that the glued part of the ring is in contact with the heavy disc. If the ring lies on plywood, glue the ring to it, and if the disc is of metal, then use Plasticine to fix the ring on the disc.

The device is ready. The disc should be suspended so that it is strictly horizontal and the ring remains circular. Should the ring compress under gravity, replace it having selected a stronger, stiffer paper. Check the ring: compress it slightly and let it go – it must regain the circular configuration.

Just above the ring, on the rope install a small clip, a piece of

black paper. It should be a tight fit but so that it could be readily removed, if necessary.

And now let us begin our experiment.

Just under the upper support insert a round stick between the ropes and wind up the disc with the ring completely. When you let go of it, it will rotate speedily on the untwisting ropes. To accelerate the disc, press on the stick inserted between the ropes. When the disc has gained sufficient speed step aside and observe the paper ring. It will have flattened out a bit. Thus you observe a transparent ellipsoid that differs from a sphere by being somewhat flattened. The clip on the ropes will indicate the amount the ring has flattened in rotation. After the rotation ceases, the ring will regain its initial (circular) form and rise to meet the clip. But it might be that the ring would not just reach the clip because of so-called residual deformation in the paper.

We again turn to the Earth. It is not an ideal sphere but is slightly compressed from poles. Recent evidence shows that the

Clip
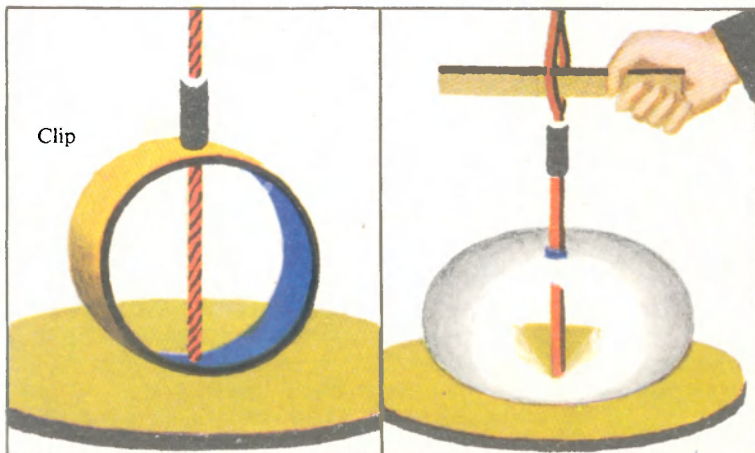
Earth's radius from its pole to the centre differs from the "equatorial radius" by 21,383 kilometres. And Isaac Newton estimated the difference to be 24 kilometres.

Isaac Newton proved that the Earth is flattened at poles (and its equatorial region is somewhat expanded, or inflated).

He maintained that the Earth had become so when in a soft state.

All the hypotheses of the origin of the Earth (be it the Kant-Laplace hypothesis that the Earth had formed of hot matter and had initially been a liquid fire-ball; or the Schmidt hypothesis by which the Earth had formed from fine particles of dust clouds and rarefied gases sticking gradually together) assume that, in its earliest days, the Earth was not solid. Hence, the fast rotation of the "soft" Earth about its axis resulted in the "inflation" of the equatorial" regions.

The terrestrial axis is inclined with respect to its orbit. The angle is 66°33.5′.

Newton attributed the precession of the terrestrial axis to the axis being inclined and to the flattened shape of the Earth.

With an ideal sphere there were no precession, but with the present shape, not all the points of the Earth are pulled by an equal force of attraction to the Sun and the Moon, thus giving rise to a "turning moment". It is this moment that "seeks" to turn the axis vertically. And, as a result, the Earth's rotational axis moves about a precession cone. A complete turn of the end of the terrestrial axis around the perpendicular to the orbit plane, that is the precession axis, takes about 26,000 years. So you see that the axis rotates fairly slowly, of course by our standards.

In order to see how the terrestrial precession came about, we will make a small model and improve the top that we made earlier from the cinefilm can. It should be made heavier and its axis changed. The axis can be made of a straight nail with the cap cut off and the other end sharpened. Drill a hole in the nail for the driving rope and add some clay into the can to make it heavier.

Now fabricate two frames to hold the top. One (internal) frame should be made from a copper or brass tube, its sides dimensioned to suit the top. On opposite sides of the frame make holes to receive the top. The hole in the tube for the lower end of the top axis should not be drilled all the way through, so that the axis can push against the inner side of the tube. But for the upper end the hole should be drilled right through the both tube walls. This will enable the top to be freely installed into and removed from the frame. Where there are bends in the frame the tube will crumple, but this will in no way affect the quality of the frame. Drill holes in the middle of the lateral sides, and insert a nail into each hole soldering the caps to the frame.

The other (external) frame will be a Π-shaped configuration, i.e., have three sides. Make it from the same tube and drill holes through its ends for the axes (nails) of the internal frame. To the middle of the horizontal section of the external frame, solder a wire hook to suspend the device. See to it that the internal frame hangs

Top precession axis

Earth's precession axis

Plane of ecliptic

Earth

Earth's axis
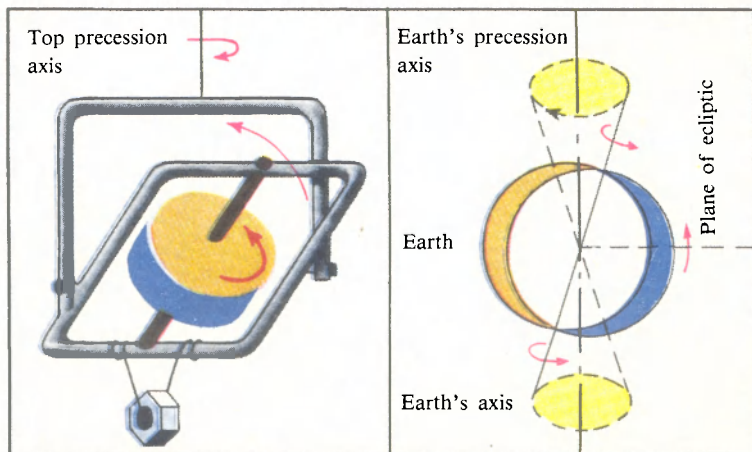
evenly without slanting.

We will now perform the experiment. Using a thin string, spin the top. It will spin in the initial position. When it comes to a halt, tie a weight as shown, bring the top into an inclined position and restart it. The weight will try to turn the frame, i.e., to bring the top axis to vertical. We will observe the phenomenon occurring with the Earth which the Sun and Moon "seek" to put upright in its orbit, i.e., without any tilt of the axis. From the outset, both frames will begin to rotate about the string from which they are suspended. The string is the precession axis for the top.

The precession motion of our device does not last long. Then the device will rotate in the opposite direction due to friction in the bearings and the unwinding of the string.

UNFELT VELOCITY.   nus, we live on a gigantic top. But we do not feel any sensation of the high-speed motion of our Earth circling the Sun. Also, we do not notice the velocity of rotation about the Earth's axis.

Granted we know that spring comes after winter, summer after spring, autumn after summer, and so forth. These seasonal variations occur gradually, we are used to them and do not associate them with the Earth speeding along at 29,765 kilometres per second. This figure tells nothing to us.

Ordinarily we measure velocity in kilometres per hour. A man walks at 6 kilometres per hour; a car and train usually travel at 40-100 kilometres per hour. Planes attain 300 to 800 or more kilometres per hour, they can travel faster, and now faster than sound, i.e., at velocity more than 1,200 kilometres per hour. Our spacecraft, orbiting the Earth, make 28,400 kilometres per hour. But the Earth circles the Sun at 107,154 kilometres per hour!

And how about the rotation of the Earth about its axis? The greatest speed is at the equator – 1,674 kilometres per hour.

But we have no feeling whatsoever of these velocities.

PROOFS OF THE EARTH'S ROTATION. Although in the 19th century not a single educated man harboured any serious doubt that the Earth rotates on its axis, and not the Sun around it, the prominent French scientist Jean-Bernard-Léon Foucault staged in 1851 an experiment to demonstrate visually the Earth's rotation.

Foucault's experiment relied on the property of a pendulum to retain the plane of swing even if its suspension point rotates about a vertical axis.

From the dome of the Pantheon in Paris Foucault suspended a 28-kilogramme iron ball by steel wire 67 metres long.

When the pendulum in Pantheon was started, it was found several minutes later that the plane of swing had changed, moving clockwise from East to West. Actually, the plane of the pendulum remained the same. During this time the Earth had turned from West to East.

In the Soviet Union there are several Foucault pendulums. The pendulum at St. Isaac's Cathedral in Leningrad is larger than its
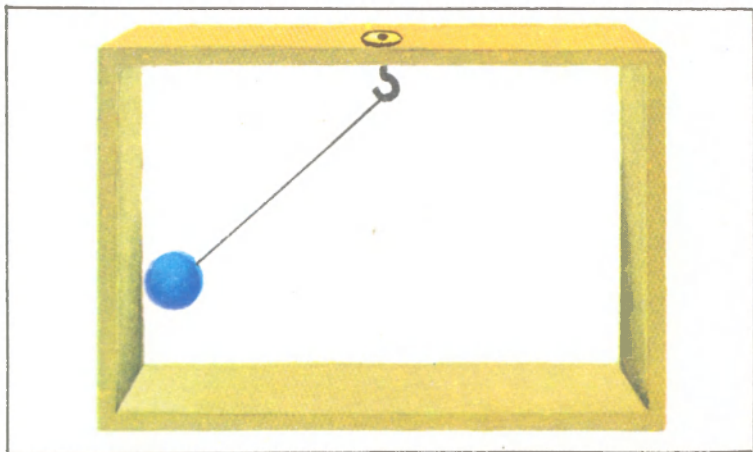
forerunner at the Pantheon, it is 98 metres long.

You can also make a small model of the Foucault pendulum.

Find a wooden board 50-60 centimetres long, 12-15 centimetres wide and 2-3 centimetres thick and fix on it a Π-shaped support, made of narrow wooden laths. The support should be 30-40 centimetres high. At the middle of the upper section drill a vertical hole and pass through it a piece of wire, bend the upper end so that it is fixed securely in the opening. At the lower end of the wire make a hook to suspend the pendulum. The hook must be free to rotate in its seat. Using a thin string suspend from the hook a heavy weight (a large nut, a large ball, etc., having wrapped it in a rag).

Swing the pendulum so that its amplitude does not exceed the length of the support. By turning the support counterclockwise about its vertical axis you reproduce in miniature the Earth's rotation from West to East. Our Earth's model turns, but the pendulum continues to swing in the plane in which it has been set in oscillation.
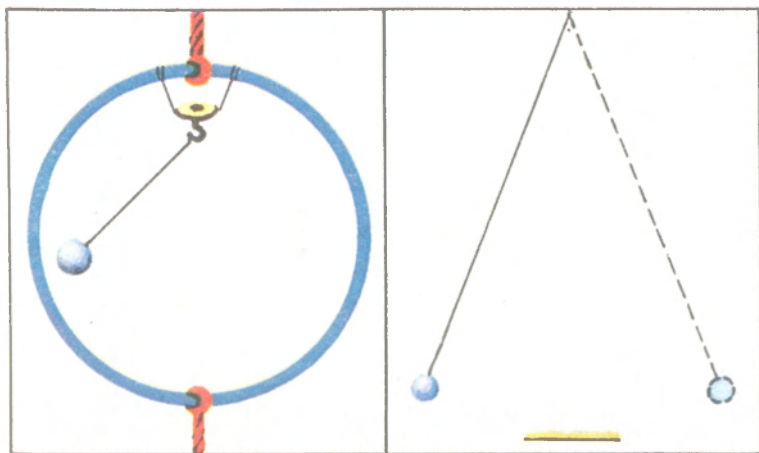
There is also a more impressive form of the experiment. Make a 50-cm dia hoop and a movable joint from thick wire. In order not to drill the wire, suspend on two thin wires, attached to the side of the hoop, a piece of tin plate with a prepared hole to receive the hook for the pendulum. Then, on a beam, suspend the entire hoop. Tie another rope to its lower part and fix the lower end of the rope tautly. The hoop will hang vertically, suspended from the ropes.

Swing the pendulum. If you start rotating the hoop about its vertical axis, this will not tell on the plane of swing of the pendulum. It will swing in the same plane in which it has been started.

If premises are available where a ceiling is 4-5 metres or more above the floor, the Foucault experiment can be carried out properly. Unfortunately, this experiment cannot be set up outdoors where it is much easier to find a high suspension point. A slightest movement in the air can distort the results of the experiment.

We will now turn to an experiment that graphically demonstrates the Earth's rotation. Adapt this description to perform the experiment in the available conditions.

Drive a thin nail into the ceiling and make a hook of thin wire that is free to rotate on the nail. Suspend from this hook with a thin string a rubber ball about 6 centimetres in diameter, filled with sand. The total length of the pendulum should be 410 centimetres and the pendulum should miss the floor by 6 centimetres. When the pendulum is started (be very careful so that the ball does not rotate about its axis and swings in only one plane), take a note of the time and place a 1-metre ruler in the plane of swing just under the pendulum. The ball will swing exactly over the ruler.

Align the plane of swing using a compass along the North-South line and observe the experiment from South. In ten minutes you will see that the plane of swing is no longer directed along the ruler, as it has been initially, but traverses the ruler in the middle. Place another ruler over the first one so that the pendulum swings now directly above it. An angle has formed between the rulers at

the point of their intersection. It would seem that the entire plane
of swing of the pendulum has turned by this angle clockwise, i.e.,
from East to West. But in actual fact, within those ten minutes the
Earth has turned from West to East together with the room and
the observers.

THE MOON ROTATES THE EARTH. It might appear incredible
that the Moon rotates the Earth. It might be argued: how possibly
can the Moon, whose mass is 81 times smaller than that of the
Earth, and which itself circles the Earth, rotate the Earth?

The Earth undergoes many rotational motions: it revolves around
the Sun, rotates on its axis, and the axis in turn precesses. But the
Earth features one more rotation – that caused by the Moon. If
there were no Moon, there would be no such rotation. The Earth
and Moon are closely connected by mutual attraction forces. To be
sure, the Earth's attraction is more powerful and this attraction
holds the Moon in its path. The Moon in turn (though assisted by
the Sun) periodically raises the water in the terrestrial oceans caus-
ing tides.

Scientists have calculated that the Moon, in its path around the
Earth, does not revolve about the Earth's centre, but around
a point separated from the centre by about 4,700 kilometres. The
point is called the centre of mass of the Earth-Moon system.

We generally use the term "centre of gravity". In a stick, for
example, the centre of gravity lies at its middle. If we place the
stick on a finger at this place, the stick will balance because its sup-
port will be directly under the centre of gravity. In a ball the centre
of gravity coincides with its centre.

But if for terrestrial objects we use the term "centre of gravity",
given that gravity is the force of attraction of bodies to the Earth,
then we use the term "centre of mass" for the Earth-Moon system.

Now let's use another small device. Take a drinking straw about
13 centimetres long and fix two balls on its ends. You could use
the wooden balls from old toys. One ball should be about 3 centi-

metres in diameter, and the other, 1 centimetre. The mass of the
large ball (by mass we mean inertial mass) must be several times
larger than that of the smaller one. Place the rod with the balls on
the edge of a knife, as shown, and move the knife till you attain an
equilibrium. This will be the centre of gravity of our system that
consists of two balls, we can ignore the mass of the straw. At the
point where the centre of gravity of our system lies (closer to the
larger ball) tie two pieces of string 70 centimetres long. Tie the
other ends of the strings to two horizontal beams, e.g., a door
jamb. It is important that the device hangs freely without any con-
tact with other objects.

By moving the strings along the straw obtain the best balance to
the device. Now rotate it to wind the strings up as hard as possible.
After you have finished winding, hold the strings with one hand
and check to see if the support point still coincides with the centre
of gravity. When the beam is strictly horizontal and does not
swing, let go of it. It will begin to rotate about the support point.
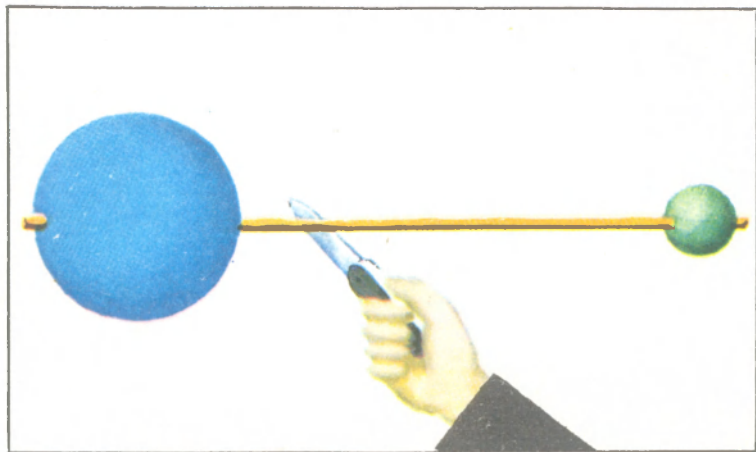
Notice that the strings are the axis of our device, and are strictly vertical, subject to no force seeking to displace them from vertical. When the device stops rotating, it will hang motionless in the horizontal plane.

The experiment can be performed the other way. Shift the strings by one centimetre along the straw in the direction of the smaller ball. Wind up again and wait till the device is stationary. Let it go carefully. As the rotation begins note the behaviour of the strings. They are no longer vertical but circumscribe a cone. And now the axis of our device is the axis of this cone. But the axis still passes through the centre of gravity of the two balls.

Perform this experiment several times, each time shifting the suspension point closer to the smaller ball. The straw, when rotating quickly, is now strongly inclined and makes two cones. Their apexes met at one fixed point, the centre of gravity of this small system. Of especial interest is the rotation of the device when it is suspended at the very middle of the straw or near the smaller ball.

But back to space. Now, how does the Moon rotate the Earth? You are sure to have surmised that the experiments just performed have something to do with the Earth-Moon system. The part of the straw connecting the balls in this experiment is played by the attraction of the Moon to the Earth, and of the Earth to the Moon. As mentioned, the centre of mass of this cosmic system is separated by 4,700 kilometres from the geometrical centre of the Earth. It will be recalled that the equatorial radius of the Earth is 6,378 kilometres, hence, the centre of mass of the Earth-Moon system lies within the globe.

In a complete turn of the Moon round the Earth the geometrical centre of the Earth, too, makes a complete turn about the centre of mass of the Earth-Moon system.

Let us make a very simplified model demonstrating the rotation of the Earth-Moon system. We will not try to observe the scale and the mass ratio, besides the Moon will revolve not in an elliptical, but a circular orbit.

Make a ball about 3 centimetres in diameter from some Plasti-
cine. This will be our "Earth". Then tie two strings very tightly to
a straw, 2.5 centimetres away from one end, so that the strings do
not shift out of place. The straw should pass strictly through the
diameter of the ball. The strings will cut through the Plasticine and
emerge above the place to which they have been tied.

Close carefully the cut through the Plasticine and see to it that
the strings do not shift. The place of attachment of strings to the
straw will be the centre of mass of our device. Now suspend the
device from the strings and fix a smaller Plasticine ball on the
other end. Before molding the ball take some Plasticine, attach it to
the end of the straw and attain a full balance by removing or
adding Plasticine. The assembly must hang horizontally. Next
remove the Plasticine, roll it into a small ball, the "Moon", and
put it back on the straw.

Check that the device hangs strictly horizontally, then wind up
the strings. When it has settled down, let it go. Our model of the

Geometrical centre of "Earth"

"Earth"
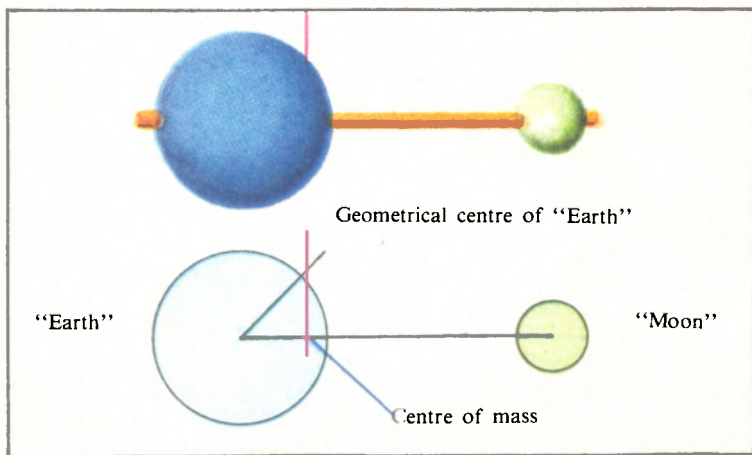
"Moon"

Centre of mass

Earth-Moon system will rotate. The "Moon" will revolve about the "Earth", and the geometrical centre of the Plasticine "Earth" separated from the suspension point, i.e., the centre of mass, by one centimetre will move in a circle around this centre. The strings will be vertical, if the system is well balanced.

The above experiments have dramatically shown the importance of the correct alignment of various rotating parts of a machine: fly wheels, turbine rotors, electric motor rotors, and shafts. It is most important that the axis of a part passes through the centre of gravity, in order that no vibration is generated that is damaging to the entire machine, wears the bearings and shakes the foundations.

OPTICAL TOUR TO THE COSMOS. In 1611 the eminent German astronomer Johannes Kepler made an astronomical tube that might be called the grandfather of modern refracting telescopes. The astronomical tube has been constantly improved: the quality and dimensions of lenses increased, the mechanisms developed to train the telescope onto a definite region in the skies, devices invented to maintain a constant observation point irrespective of the Earth's rotation. In short, the astronomical tube has been turned into the powerful, clever telescope. Using such telescopes, scientists can penetrate ever deeper with their sight into the far corners of the Universe. So they can now become much more intimately acquainted with the planets of the Solar system. Some of them were found to have moons, previously unknown; and comets, too, can be better watched.

Through Boundless Space and Time

Besides the optical telescopes, gaining ever increasing recognition are now radio and X-ray telescopes. They enable us not only to study the external features of celestial bodies, but can also sometimes identify the processes occurring in their bowels.

Radiotelescopes provide evidence to astronomers about a wide variety of fascinating events occurring in most remote sections of the Galaxy and beyond, in other stellar systems.

By capturing the radio signals and X-rays coming from space, scientists can glean a great quantity of new data. But not on what happens now. We only can learn, in this way, about what took place many years back. From several years to thousands, millions, and even billiards of years ago! The velocity of light and radio waves is 300,000 kilometres per second. This is the largest velocity possible in nature. The light of the Sun, too, takes some time to come to us, i.e., 8.3 minutes after its "departure" from the solar surface.

However, by correlating various observations and dealing, in essence, with the past of our Universe we can judge about what occurs in it now.

HOW TO MAKE A REFRACTING TELESCOPE. Optical telescopes come in two varieties: refractors and reflectors.

In refracting telescopes, or refractors, the optical system consists of lenses. Both the objective (the optical system at the front of the telescope) and the eyepiece (the optical system used to look at the image made by the objective) are lenses. In reflecting telescopes the object studied is caught by a parabolic mirror, and then the image produced is viewed with an eyepiece that is essentially a system of lenses.

We will now make a refracting telescope because suitable lenses are readily available and it is easy to manufacture. By contrast, the parabolic mirror for a reflecting telescope must be ground on your own, which is a rather arduous and time-consuming business.

Objective   Eyepiece
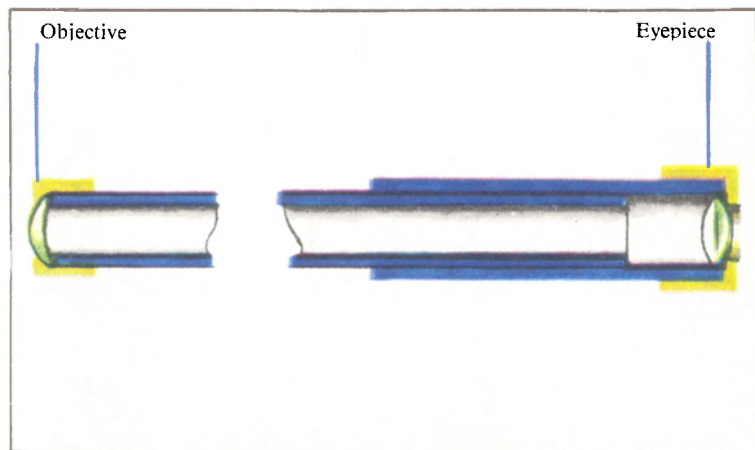
Our telescope will enable us to make fascinating "tours" of the skies when there are no clouds, of course, and it is sufficiently warm outdoors. It is not convenient to watch the starry skies from indoors, besides window glass will distort the image. The telescope will allow us to study the Moon, planets and stars and its magnification may be hundred-fold. Observing, say, Mars during its opposition, i.e., when it gets closest to us, you will see a reddish spot the size of a pea, viewed at 30 centimetres.

We will need two lenses, several sheets of thick paper and glue. The lens for the eyepiece can be bought from a chemist and we require a +0.5 diopter lens. The lens could have irregular periphery, it is immaterial. The diameter should be about 5 centimetres and the diameter of the tube being suited to that of the lens.

For the eyepiece we will need a magnifying glass with a focal length of 2 centimetres. The glass's diameter is of no importance, but preferably it should be no more than 5 centimetres. The main tube of the telescope should be 1.9 metres long, and together with the eyepiece tube it will be 2 metres long.

Should you fail to get a +0.5 diopter lens, take a +1 diopter. But now the length of the telescope should be 1 metre. For the same eyepiece this will now have a magnification of 50. This magnification, too, is sufficient for many interesting observations, but the image will be smaller though more distinct.

To make the main tube take a sheet of strong paper, roll it into a tube onto a smooth stick or tube with a diameter of about 5 centimetres. Then straighten the sheet to see how much paper is required for the inner surface of the tube. Cover this part of the sheet with a black paint that is not glossy (e.g., by black gouache). Next paste the edge of the sheet with glue, and rolling it again on the same stick, furl the rest of the sheet. Cover the inside of the other edge with glue to ensure that the tube does not unroll. See to it that the tube is rolled taut and all the layers stick to one another. For the 1.9-metre tube it might be necessary to make another similar tube and then butt-joint them by covering the joint with two or

more layers of paper and gluing the internal side of the sheet spar-
ingly. If you plan to take your telescope out on a journey, then the
joint should allow you to disconnect easily one section from the
other.

To make the eyepiece use the same paper and glue together
a tube 20 centimetres long. Its internal diameter should be some-
what larger than the inner diameter of the larger tube and the eye-
piece should be a smooth sliding fit on the main tube. After the
two tubes have been prepared, insert the lenses into them.

Use the same paper or thin cardboard to produce two caps: one
for the eyepiece end of the tube, the other for the objective end. In
the middle of each cap, cut a hole somewhat smaller in diameter
than our lenses. Having placed a lens exactly in the middle, put
a ring rim of strong paper over the lens and secure it with glue. Now
you can remove the caps with the lenses when required, clean the
lenses with a clean rag, and place them in a box to keep them away
from dust.

The eyepiece lens must be installed with its convexity outwards.
It is a good idea to cover the outside of the telescope tube with oil
paint and leave it to dry fully.

Use the paste employed to apply wall-paper to glue large tube.
For the caps, the glass holders, a synthetic or other glue good for
paper is more suitable. When gluing be careful not to spoil the
glasses as these must be perfectly clean. Hold a lens with two
fingers by touching the opposite edges.

Before setting the lenses, wash them with soap (if the lenses are
not glued), allow them to dry and wipe them with a clean, beize
rag.

It only remains now to make one more important part of the
telescope – the mounting. It is impossible to use the telescope with-
out a mounting. In order to get the telescope working properly
choose a height so that when you are sitting on a folding chair you
can observe, with ease, the various parts of the sky, from the Pole
Star (overhead) to the horizon.

Your mounting could be a combination of a stationary tripod and a telescoping, turning mount.

The legs of the tripod should be made of wooden sticks about 120 centimetres long, and a cross-sectional area of 2×4 centimetre. Cut a triangle with sides about 12 centimetres long from a 4-cm thick board. Drill a hole at the centre of the triangle to receive a round stick about 2 centimetres in diameter. This will be a mount of your telescope. The mount must have holes drilled at 5-cm intervals to insert a split pin, as shown.

Prune the angles of the triangle and attach to it on hinges the sharpened legs, as shown. At the top of the mount attach a wooden ring with two screws. Using a wing-nut, fix to the latter a second ring that can be turned on the screw. As the wing-nut is screwed home, it must force one ring firmly against the other. To the second ring, along a chord, attach a wooden lath 50-60 centimetres long. To its ends, and normal to it, fix two plywood rings 12-15 centimetres in diameter. Secure some jacks to receive the telescope
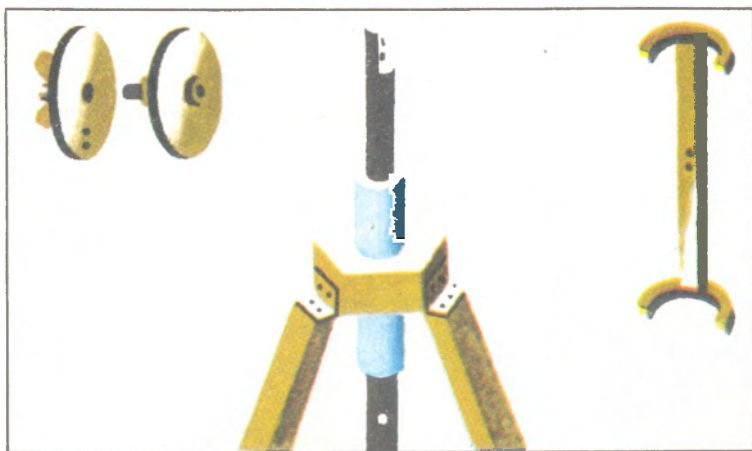
in the rings and to the rings tie some strings to secure the telescope in place. All the wooden components of the mounting should be well sanded down, painted and varnished.

This is a description of a simple tripod, but you can improve it. For example, the mounting could be made of metal: instead of the round wooden stick use an aluminium tube; and make all the other fittings of the metal available.

Height adjustment is provided by sliding the mount up and down. A wooden pin, inserted into a hole in the mount, will not allow the telescope assembly to slide down. For the mount to move strictly vertically through the wooden triangle, drive a short piece of metal tube through the wooden hole to hold the mount. This will make the system more stable and the telescope will swivel freely.

The telescope is tilted by turning the ring with the lath about the bolt with the wing-nut. The nut securely fixes the tube in a desired position.

The adjustment and lining-up of tilting and turning parts requires special attention. You will need to turn the telescope constantly even when it has already been pointed at an object of your investigation since the Earth keeps rotating and the object being observed slips out of the field of vision. In observatories each telescope has a mechanism to rotate it with the same velocity that the Earth "leads it away" from the object of observation. As a result, the telescope appears to be tenaciously trained at a required point in the skies, for the astronomer to be comfortably engrossed in his photographing and observing.

When everything is ready and the telescope is fixed securely in the jacks, turn the tube horizontally and point it at a remote object (a tree, house, lamp-post, etc.). This test is better by day. The telescope should be pointed at the object as if you are going to fire a gun and are taking good aim. The "target" should lie on a line passing over the very top of the tube. The tube has neither a front sight, nor a sight frame, but these can be easily imagined. And

after the "target" has been caught, the objective can be readily trained at the object. Looking through the eyepiece, adjust it till you obtain a sharp image. The image will be "upside down" but this is absolutely immaterial in observing celestial bodies.

The image sharpness is determined by the alignment of lenses in your telescope. Lens centres in the objective and eyepiece must lie along the tube axis. To check the alignment rotate the tube of the eyepiece while watching the object. If the image remains unchanged, the alignment is correct. Now wait for the evening with, of course, cloudless skies to begin your exciting journey over the heavens.

The telescope will acquaint you with many of the planets of the solar system and with the lunar craters and "seas". True, stars will look almost as without the telescope, only a bit brighter, but the telescope will show you the stars not to be seen by the naked eye.

For those who will be fascinated by astronomy, and it is hard not to be so, we might recommend the books:

W. M. Baxter, *The Sun and the Amateur Astronomer*, David and Charles, 1973.

J. Muirden, *Astronomy with Binoculars*, Faber and Faber, 1976.

G. S. Hawkins, *Beyond Stonehenge*, Harper and Row, 1973.

In order that you may set out on your journey not "blindfolded", purchase a suitable "guide of the skies". A beginner's guide is found, for example in *Discovering Astronomy* (Longman) by Jacqueline & Simon Mitton. The book contains simple star maps for various seasons.

WHAT MAKES ASTRONOMERS UNHAPPY. What really? They have beautiful observatories equipped with the very latest modern telescopes and other clever devices. These enable them not only to investigate the members of the Sun's family and the stars of our Galaxy, but also to unveil the mysteries of other galaxies. Astronomers are quite happy with their equipment, but not with ... the Earth's atmosphere. This sounds a little strange as life on Earth

is only possible because of the atmosphere and solar energy. How can one possibly bear a grudge against what gives us life?

The blanket of atmosphere however also refracts some of the light rays coming from the planets, stars, and other galaxies, with the result that their image appears to be somewhat distorted. In addition, the atmosphere also affects the reception of radio signals coming from the far reaches of the Universe. The atmosphere contains vapours and dust particles, let alone the fact that clouds can cover the heavens at a most unhappy moment.

The cherished dream of all astronomers is to get into space, beyond the terrestrial atmosphere, to do their observing without any interferences. But astronomers are still ground-bound and it is only the astronauts on an orbital lab that can enjoy viewing far-off worlds without the disadvantage of the atmosphere. Therefore, astronauts are assailed by astronomers before setting out on a space mission. The orbital labs have first-class equipment, given that the size of the telescopes is understandably limited. From their space travels astronauts bring back photographic pictures or film, curves plotted on paper tapes, and the results of a variety of observations and trials. On Earth, scientists thoroughly investigate the evidence gleaned and work out the tasks for further missions.

However, our astronomical studies will not be greatly influenced by the atmosphere, and we will be satisfied with our instruments and conditions.

COLOUR MESSAGES FROM DISTANT WORLDS. Apart from optical telescopes enabling us to observe far-off worlds or take picture of individual parts of the sky for a study at leisure, special-purpose devices exist to catch the radio signals produced by the complex physical processes occurring in remote parts of our Galaxy. Also, there are facilities for studying cosmic rays. Using a suitable X-ray telescope, astronomers survey the Sun and stars that send out X-rays.

But there is still another very interesting way of exploring cosmic

objects that makes it possible to find out what the elemental composition of a star is and to work out the velocity at which it travels.

The technique is called the spectral analysis. Using special instruments, the spectrographs, astronomers receive from space sort of coded messages. The decoding of the colour language of the messages tells the scientists much about our Universe.

To see how the colour messages are decoded we first perform several experiments.

LIGHT SPOT AND ITS TRANSFORMATION. We will experiment with sunlight. We will need a glass prism, but if it is not available you can use a mirror made of thick glass. The mirror's edges are always slanted. Take a small mirror and direct a light spot onto the large mirror. Striking the surface of the mirror at a small angle the beam will reflect from the amalgam and come out

Beam

Amalgam

Glass
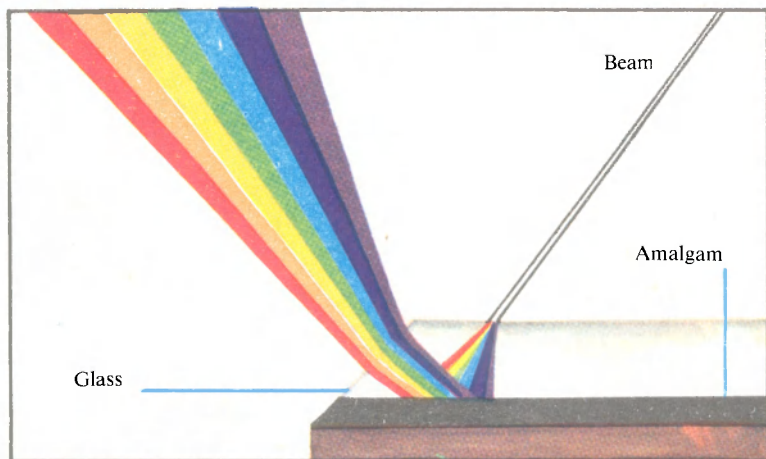
through the slanted edge to produce on the wall or a sheet of paper a coloured halo, the rainbow or spectrum.

Sometimes a rainbow occurs in the room by chance. On a clear day you may find opposite the mirror on the ceiling or wall a beautifully coloured halo.

Each colour of the rainbow shades gradually into another, but Isaac Newton distinguished seven separate colours:
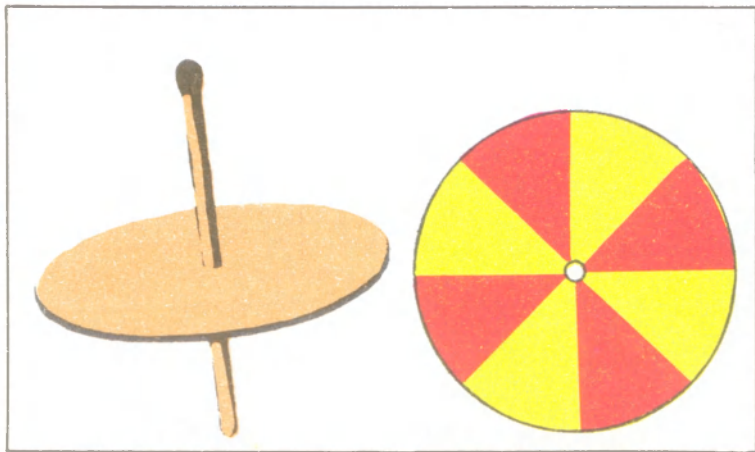
Red

Orange
Yellow

Green
Blue

Indigo
Violet

Individual colours can be played with. For example, we can "mix" two principal odd or even colours to obtain the third colour

inbetween.

So, red and yellow give orange; orange and green, yellow; yellow and light blue, green; green and blue, light blue.

Under laboratory conditions it is more convenient to mix colours using projection lights and a set of coloured glasses, light filters. We do not have these, therefore, we will mix various paints instead of the various spectral colours. To this end, we will use good watercolours and a makeshift top.

Cut out several discs 4.5-5 centimetres across from white drawing paper and a similar disc from stiff card. Divide the paper discs into eight equal sectors. Pencil the lines slightly for the desired colour not to be spoiled too much. Fill in the sectors in turn by the colours you are going to mix. For instance, one sector may be red, another yellow, again red, next yellow, and so forth. Do not apply the colour too densely but in the way it is customarily done in water-colour technique, i.e., so that a colour be deep enough and show through the paper. The paint should be distributed uniformly, without drips. Before applying the paint wet the sector to be painted with clean water, remove excess water and, onto the surface thus prepared, apply the prediluted paint. After the paint has dried, smooth the disc out, fix it on the card disc and stick a sharpened match into the middle of the sandwich. Set the top thus obtained in rotation and you will see the colour produced by mixing the red and yellow – orange.

To run the experiment repeatedly, it is recommended that you glue the white paper to the cardboard disc and cut out as many discs as there are pairs of colours you plan to mix.

You can also perform other experiments on mixing. The spectrum includes the so-called complimentary colours. Mixing them optically gives white. Examples are: red and cyan, orange and light blue, and magenta and green. If we mix red, green and blue with our top we also obtain white.

Red, green and blue are the principal hues in colour photography, cinema and television.

Your tops, of course, will not give pure white, as even the best water-colours contain some admixtures. The lighter and more transparent the colour, the better your result.

The word colour is a misnomer as applied to white and black. Strictly speaking, there is no white colour, only the optical sum of all the colours. Nor is there a black colour. Black is the total absence of any colour and light in general. But it is just customary, along with all spectral colours, to speak about "black colour", and "white colour".

Artists mix pigments a lot. There was an artistic school, Pointilism, in which tiny dots of contrasting pigment were scientifically chosen to blend, from a distance, into a single colour.

THE INEVITABLE TALK ABOUT WAVES. Why does a glass prism split a beam of white light into rainbow colours? Why really?

Light, the usual white light, that the Sun sends out lavishly and that comes to us, with a time lag of 8 minutes, is complex in composition. Scientists have found that light propagates in waves, that it indeed has a wave nature. But light waves are extremely short electromagnetic waves, just like those used to broadcast radio and TV programmes. The only difference is that the length of radio waves is measured in metres and centimetres, but that of light waves, in millionths of a millimetre.

A beam of white light consists of several coloured beams, but we do not perceive them individually. When the beam passes through a glass prism, the latter sorts the coloured beams out and arranges them to yield the coloured spectrum.

The longest waves (within the visible light band) are red ones and these are deflected the least by the prism. The shortest are violet waves, and these are deflected the most. The other colours are arranged inbetween.

WHAT CAN THE SPECTRUM TELL US? Scientists have developed an instrument, the spectroscope, that produces a very wide

spectrum with the colours shading gradually into the other. The spectroscope has a scale showing where each colour belongs. It has been found experimentally that hot solids give a continuous spectrum, and hot gases do not. They yield several colour bands, which are so narrow as to be considered lines. So, hot sodium vapour only gives two closely spaced yellow lines.

If a section of a continuous spectrum is viewed through a relatively cold, i.e., not glowing, sodium vapour, two closely spaced black lines will be seen at the place on the spectroscope scale where the yellow lines of hot sodium have been observed. It follows that the sodium vapours have transmitted all the other colours of the spectrum and have only absorbed the colours that they send out when hot.

In the continuous spectra of the Sun and stars there are many black lines. The fact is that sun (or star) light is given off by a hot medium as a continuous spectrum. But the solar or stellar atmosphere, though consisting of hot gases, is much cooler than the hot source of the light, therefore each gas absorbs its share of spectrum in its own way.

The continuous field of the spectrum in the spectroscope shows a multitude of black lines. They are decoded as follows: each group of lines belongs to a certain gas. By grouping the lines we can deduce which gases are present on the Sun or a star.

Interestingly, scientists have found on the Sun and stars only those elements which occur on Earth.

A case is recorded when, using the spectroscope, a gas was found on the Sun that had been unknown on Earth. It was called Helium, after the Sun. And it was only after 26 years that the gas was found on Earth, too. It is the second lightest gas after hydrogen and is now widely used in industry and research.

Now use water-colours to make a continuous spectrum in a frame as shown in the accompanying figure. On a sheet of clear cellophane draw an identical frame with India ink, apply the cellophane to the sodium spectrum and you will see a yellow line (for

Oxidiser depot · Control site · Pad · Service tower · Umbilical tower · Fuel depot · Instrument tower · Launch control centre · Assembly and test area · Vertical assembly area · Compressor station · Shelter
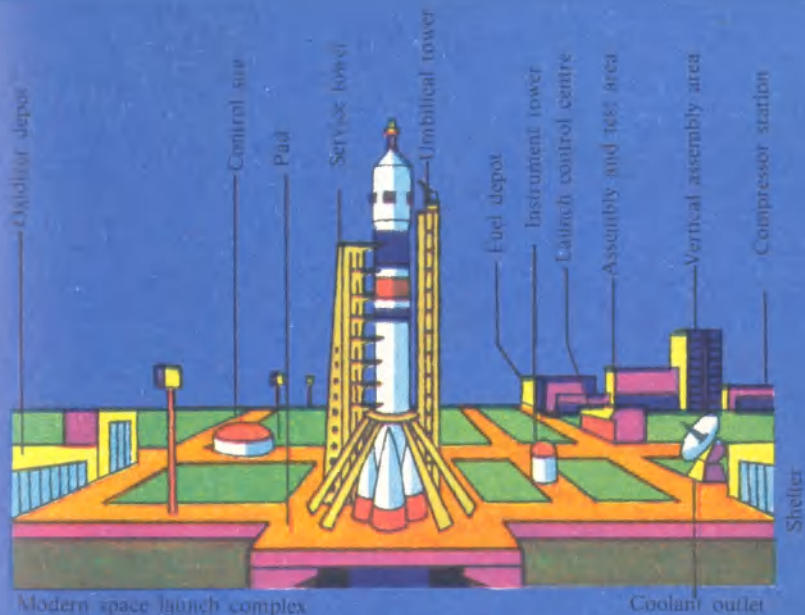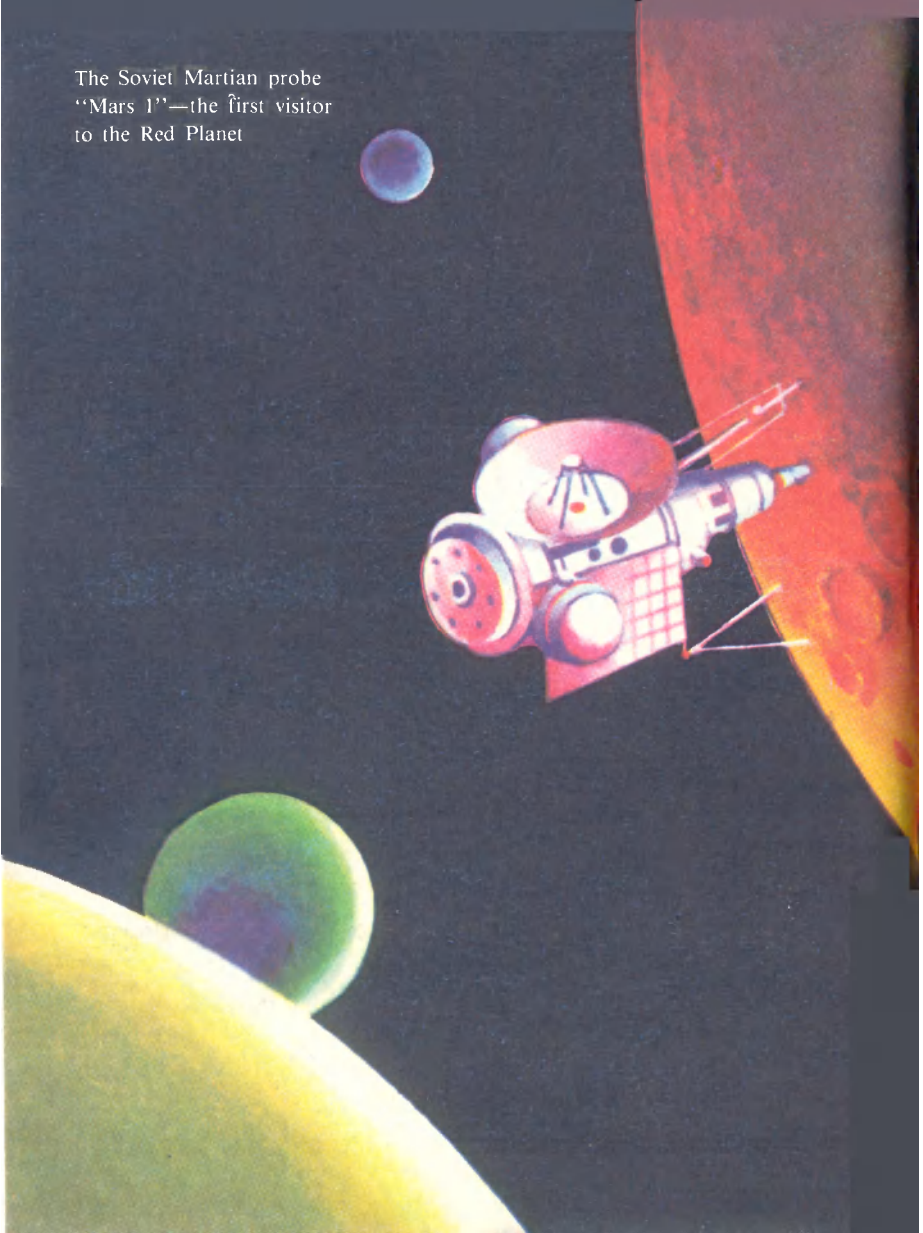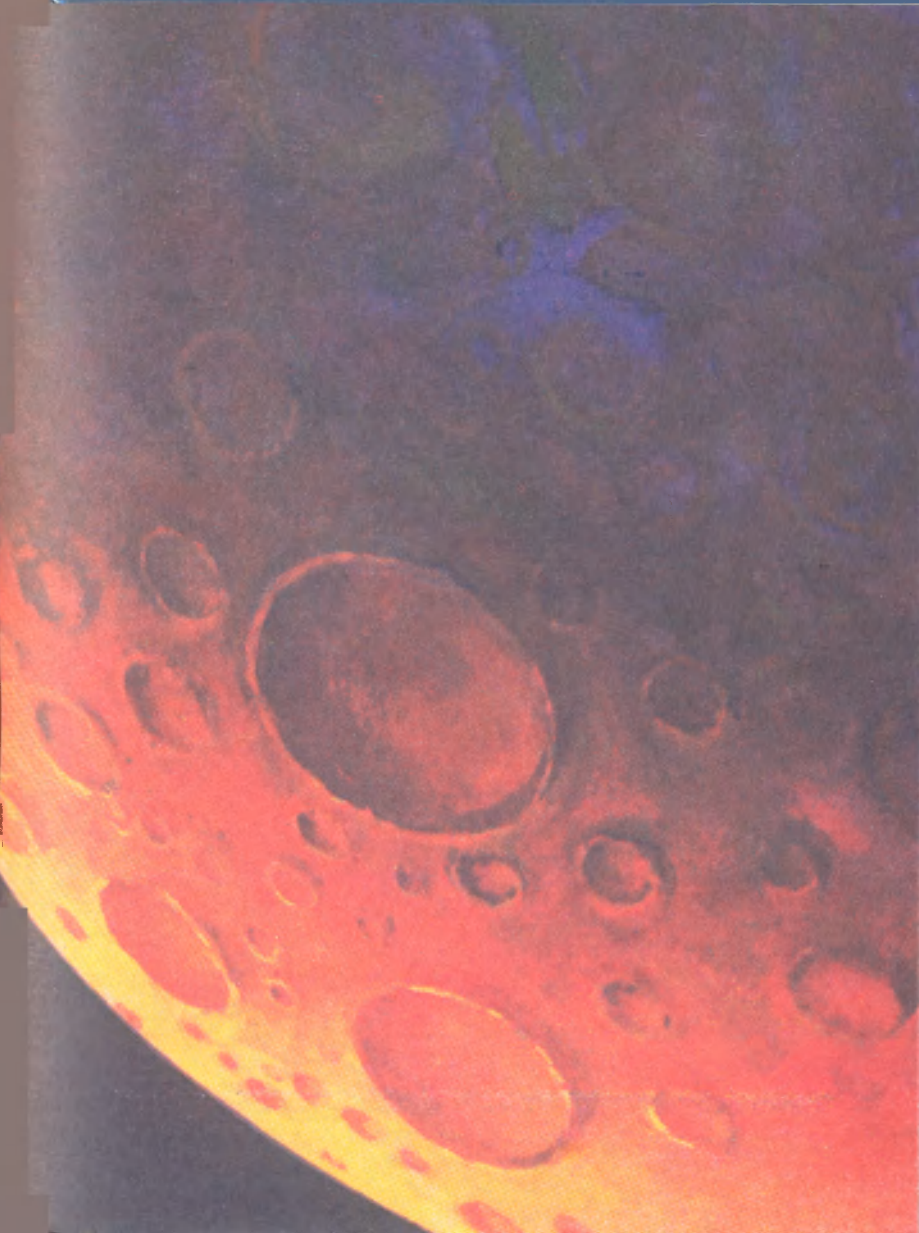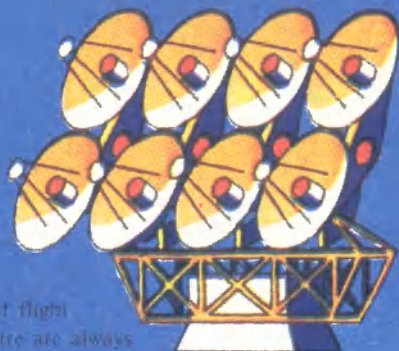
Modern space launch complex

Coolant outlet

Flight control centre

The Soviet Martian probe "Mars 1"—the first visitor to the Red Planet

Earth "listens" to space

Antennas of flight control centre are always operating

Research ship "Cosmonaut Vladimir Komarov"

Research ship "Cosmonaut Yuri Gagarin"

simplicity only one line is shown, though in fact there are two thin yellow lines). Draw on the cellophane a black line of the equal size with India ink. After the ink has dried, apply the cellophane to your continuous spectrum. You will thus obtain the sodium absorption spectrum. It may well be asked why should one take all this trouble, when the coloured table shows this. But in fact the cellophane sheet in your hands is a substitute for the sodium vapours through which you are viewing the continuous spectrum. Remove the "sodium vapours" and the spectrum again will be without the "correction". Apply it, and a black line will appear on the spectrum, the "autograph" of sodium.

In physics textbooks you may encounter a solar spectrum with black lines seen distinctly in the spectroscope. This is accounted for by the cooler gases in the solar atmosphere that have each absorbed their respective share of the continuous spectrum. But during a total eclipse of the Sun, when the Moon does a favour to the astronomers by blotting out the whole of the disc, it is only the hot glowing solar atmosphere that remains uncovered. Now the spectroscope shows the spectrum of this atmosphere, the Sun's corona. And where on the spectroscope scale black lines had previously been observed, colour lines now make their appearance representing the gases contained in the hot solar atmosphere. These lines are emitted and speak in their inherent colour language. The upper layers of the solar atmosphere, though hot and shimmering, are regarded as the coolest region of the Sun. The temperature inside the Sun soars to an amazing 20,000,000° C, but the solar photosphere, arbitrarily taken to be the surface of the Sun, has a temperature as low as 6,000° C. The hot solar atmosphere is cooler still.

You can observe solar eclipses through a sooted glass. A better idea is to develop an exposed photographic plate. You will thus have a glass plate with a smooth black surface, very convenient for observations. When viewing the Sun through such a plate, you will see just a subdued light disc.

Continuous spectrum

Emission spectrum for sodium
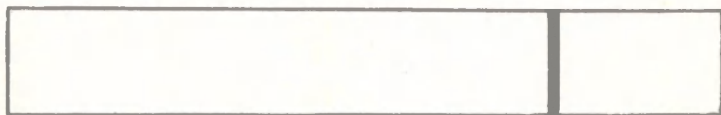
Cellophane

Sodium line

Absorption spectrum for sodium

"RAINBOW" IN SPACE. "Striking beauty!", wrote the first man in space, Yuri Gagarin. He went on to write: "When I watched the horizon, I saw distinctly the sharp, contrasted transition from the light surface of the Earth to pitch dark skies. Our planet was sort of surrounded by a bluish halo. Then this band darkens gradually, becomes violet and eventually black. The transition is far too beautiful to be described by words. Even in our powerful Russian language, it seems, there are no appropriate similes to describe the picture.

"As the spacecraft passes from the shadow side to the sunny side, the picture of the Earth changes. At first, a bright orange ribbon appears. Then, gradually, it shades into the familiar bluish, and on into the dark violet and black hues. The range of colours is indescribable. It will stay engraved on my mind for a long time."

The second flight in space was performed by the Soviet cosmonaut Herman Stepanovich Titov. He took several colour pictures of the Earth from space. One of the pictures taken at the instant the spaceship comes out of the Earth's shadow shows a rainbow halo round the annular terrestrial horizon, described by Gagarin.

The Earth's atmosphere acts as a colossal prism splitting the sunlight into its component colours.

Of course, no photograph is able to reproduce the richness of colours observed in nature.

An experiment described below will give you an opportunity to enjoy the beauty of natural colours and you, and those present, may derive great pleasure from this.

Bright spectral colours will be produced not only by the refraction of light in a prism, but by diffraction. And this proves a simple and widely accessible way of obtaining at home a splendid spectrum, it is even better than using a thick mirror.

Take a record disc, preferably a long-playing one (as on the latter sound tracks are closer) and, near a window during the day, hold the disc horizontally so that the edge is on the bridge of the

nose just below the eyes. Look at the nearest side of the disc, at its sound tracks. The far edge should be in view just under the upper frame of the window. Between the upper frame and the disc the sky should be seen so that the gap through which the piece of sky is being seen is about one-two fingers widths wide.

By slightly inclining the far side of the disc you will see on the near side a bright colour bar. The angle of the disc can be adjusted to produce the brightest colours.

COSMIC PUZZLE. When looking at the spectra of distant stars, astronomers have found a strange phenomenon: in the spectra of certain stars the black lines inherent in chemical elements appear, for some reason, not where they should. True, the shift is small but still it is there! The shift varies with the stars and is mainly towards the red. This was a puzzle, but scientists were successful in cracking it, and at once put it to use. The slight shift of the spectrum lines furnishes evidence of distant stars not to be derived by other


Spectrum image   Record disk   Window
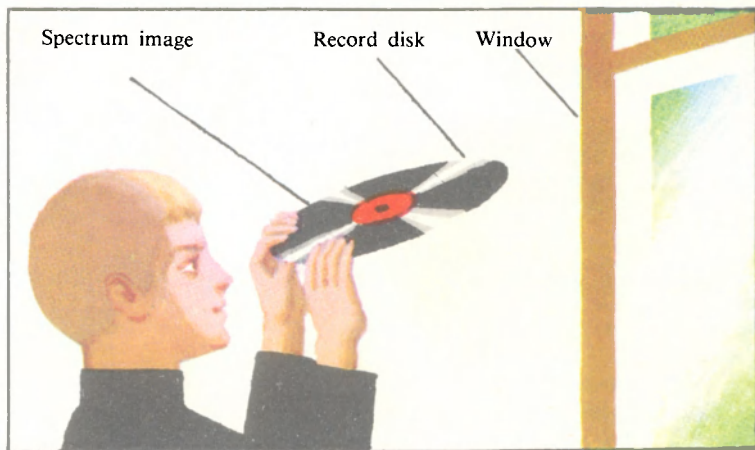
means. The phenomenon was fittingly called the "red shift". To understand better the mystery of the red shifts we will return to waves.

SOUND WAVES. Sound waves are longitudinal ones. But what do they look like? We cannot observe a longitudinal wave in nature though with light waves the situation is better as they are transverse waves. And although waves on water are a rather rough model, they still give some idea of the nature of light waves.

An idea, however crude, of longitudinal waves comes from observing accordion bellows moving back and forth. In a like manner, longitudinal waves propagate through an elastic medium by alternatively compressing and stretching it.

A sound wave travels in the air at a speed of 340 metres per second at standard temperature and humidity. Knowing the times of a flash of lightning and the clap of thunder, you can easily work out the distance to the lightning. Multiply the time lag in seconds
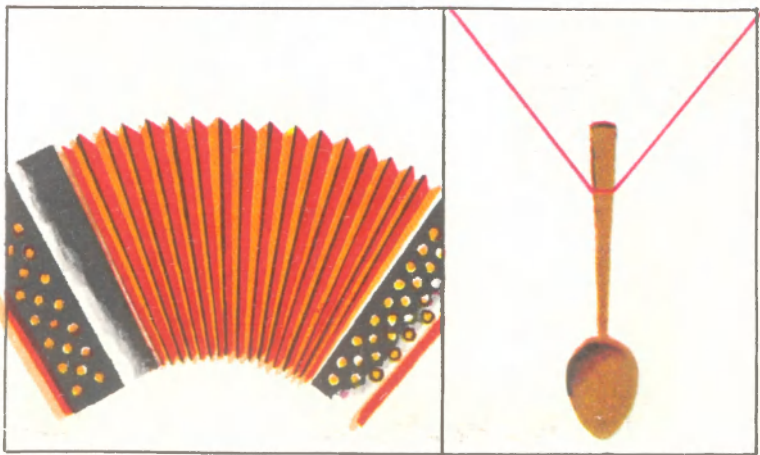
by three. The result will be the approximate distance, in hundreds of metres, to the site where the lightning had struck.

Air possesses good elasticity, to which property we owe the possibility to talk to each other and enjoy music, but still as a sound conductor it is far from ideal. The best sound conductors are solids; the second best, liquids; and the third, gases.

That air is not a perfect sound conductor you can see by carrying out the following ancient experiment.

Take a tablespoon and suspend it from two strings 30 centimetres long, as shown. Strike the spoon on the edge of a table and you will hear a faint sound. If then you bend down and press with your finger tips the ends of the two strings to your ears so that the strings will still be free to swing, and strike the spoon, you will hear a loud, beautiful ringing. The vibrations have come to your ears via the string fibres. This loud ringing is not at all like the faint sound you heard before.

We can observe how elastic vibrations propagate through solids
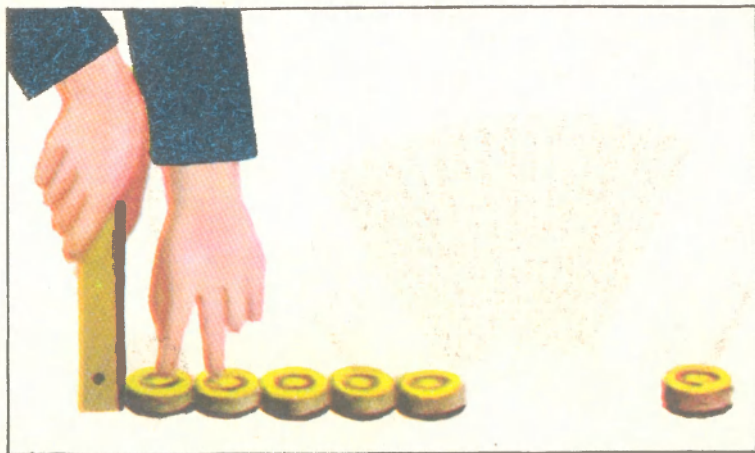
in the following experiment. Arrange some draughts (or identical coins) in a line without gaps, press the first draught down with a finger and then rap it with a ruler, as shown. The elastic vibration will pass through the first draught to the next one, etc., till it arrives at the last one. The last draught will recoil since it has not another draught to which to impart the impetus received.

PONDER OVER YOUR COMB. The wavelength of transverse waves is measured from crest to crest, or from trough to trough, of two successive waves. With longitudinal waves the wavelength is measured either from compression to compression or from rarefaction to rarefaction.

Take a comb with teeth set closer on one side than on the other. The comb teeth will show schematically the picture of longitudinal waves. The thickness of a tooth plus the gap is the length of a "wave". Work out the number of such "waves" per centimetre. For example, on one side of the comb there may be 4 teeth and

Transverse waves — Wavelength

Longitudinal waves — Wavelength
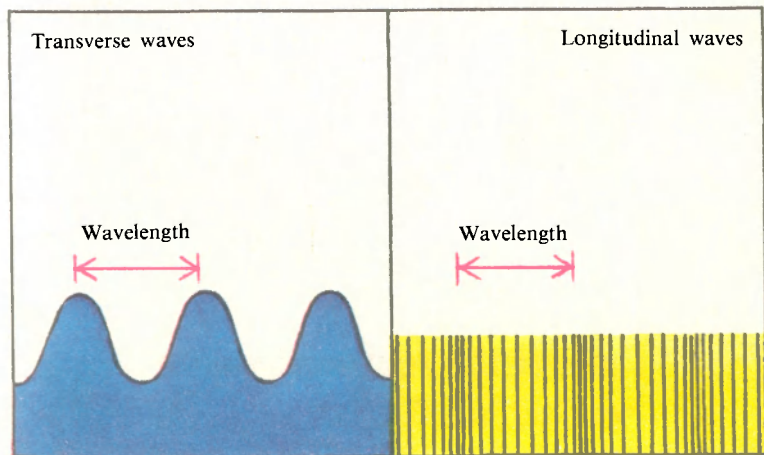
4 gaps per centimetre, i.e., four "waves", on the other, 7 teeth and 7 gaps, i.e., 7 "waves". It is obvious that the teeth are denser where there are 7 teeth per centimetre. You may also have noticed that the smaller the density of teeth, i.e., the fewer teeth there are to the centimetre, the stronger the teeth and the wider the gaps. On the closer-set side, the teeth are thinner and the gaps narrower. The implication is that the "wavelengths" on the one side are larger than on the other, being dependent on the "tooth density".

In sound and electromagnetic oscillations, the frequency is expressed in terms of oscillations per second. If the propagation speed of the oscillations is constant, then the greater the number of complete oscillations per second, the shorter the waves. Conversely, the fewer complete oscillations per second, the longer the waves.

LISTEN TO A LOCOMOTIVE WHISTLE. Speaking about sound it is customary to describe it not in terms of wavelength, but of frequency.

Frequency

1 "wave"   4 "waves" 7 "waves"
            per 1 cm   per 1 cm
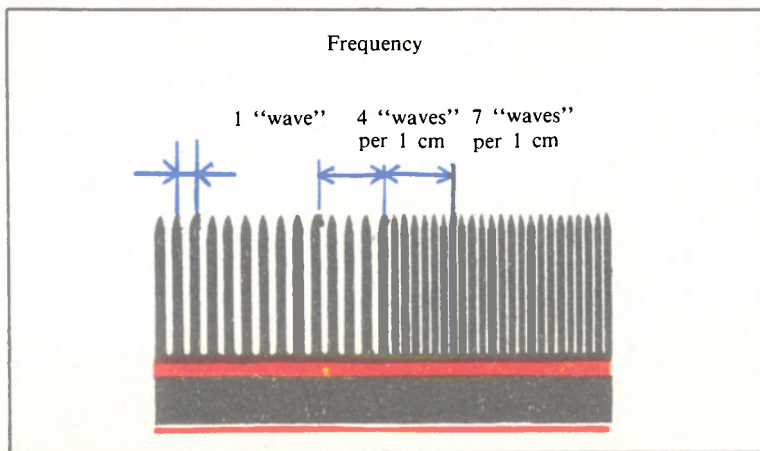
Have you ever heard how the whistle of the locomotive of an approaching train changes? If you stand far away from the railway and listen to a whistle of a passing train, you will not perceive any change in the sound pitch. But if you are travelling in a train and hear the whistle of an approaching train, you are sure to notice how its pitch changes. You may hear the whistle for a short time, maybe 2-3 seconds, but during even this short period you will perceive that at first its sound is high, but as the oncoming locomotive, having flashed past, recedes, the pitch drops to lower than normal. The result is a whine, sounding like IUAAAA, with A sound being lower than I.

The whistle sound in itself did not change, but you perceived it differently when it was approaching from when it was receding.

How does this come about? Suppose you are travelling in a train at 60 kilometres per hour. Along a nearby track a train is moving in the opposite direction at the same speed and whistles when passing you. For simplicity, suppose that the whistling locomotive is at rest and your train approaches it with a velocity of 120 kilometres per hour (it will not affect our argument). Sound waves from the locomotive propagate in all directions. And they travel to you, too, with the same velocity, but you in turn are speeding along to meet them. If you were at rest, in a second you would receive, say, 1,000 waves, but since you are approaching their source, you would catch not just 1,000 waves but many more, say, 1,200 in a single second. For the waves to cram into a second they had to become shorter, hence their frequency increased. So now we have not 1,000 but 1,200 vibrations per second. The pitch of sound always becomes higher with frequency, therefore you perceived the pitch of the whistle as higher than normal.

However, as you recede from the whistling locomotive, you receive fewer sound waves in a second. Hence, the frequency has dropped and the pitch has dropped.

It should be remembered that this only occurs in motion, either when you approach or recede quickly from the sound source.

These frequency shifts are called the Doppler effect, after the Austrian physicist and astronomer Christian Doppler, who discovered and explained the phenomenon in 1842.

THE DOPPLER EFFECT IN DRAWINGS. The following experiments are "living" pictures illustrating the Doppler effect. Models and experiments involving this effect are only illustrative as are the diagram and pictures showing wave processes. The only difference is that you will see not a stationary image, but a pattern varying under your very eyes.

We shall use two models. One is very simple, it will only compress "waves", increasing their frequency. The other is a more sophisticated model that will enable us to observe "wave" compression and rarefaction.

For the first model draw on a sheet of drawing paper, 20×25 centimetres in size, some India ink stripes about 15 centimetres long and 0.5 centimetres wide, with the gap 0.5 centimetres. The
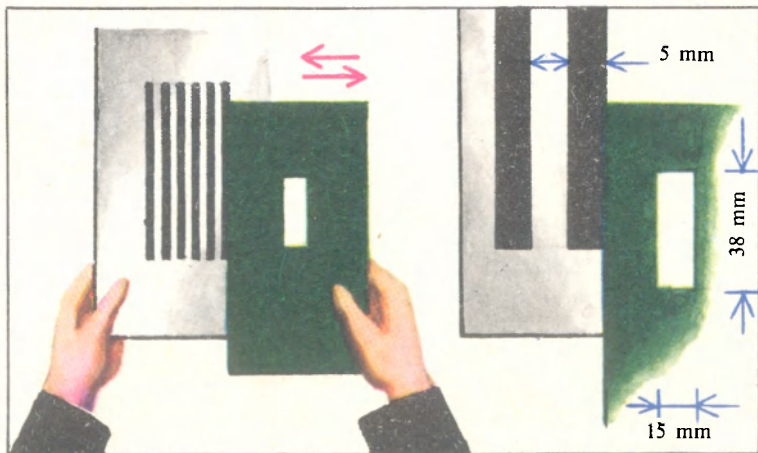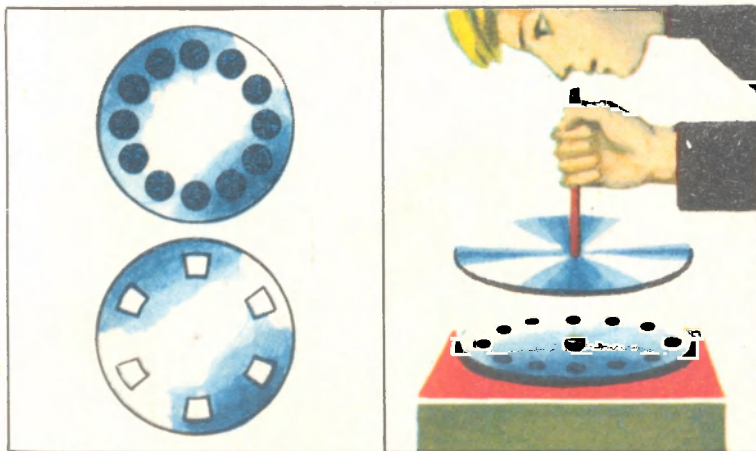
distance covered by one black stripe plus the gap will be our wave-
length, a complete oscillation.

On another sheet of paper (it can be smaller in size) make in the
centre a vertical opening 1.5×3.8 cm in size.

Now take in your left hand the sheet with the "waves" and in
your right hand the sheet with the opening. Look through the open-
ing at the vertical "waves" and begin to move the sheets quickly
relative to each other, as shown. The movements should be very
quick. You will then see, through the opening, that the "waves"
become narrower. The experiment should be performed so that you
could see unshielded black lines above the sheet with the opening.
These will serve as sort of a standard for comparison for you to see
the difference in the size of "waves" clearly above the sheet and in
the opening.

The experiment can be simplified further. Remember that when
discussing frequency we used a comb. Now take a comb and
a sheet of paper with an opening and, holding the comb horizon-

tally in your left hand and the sheet of paper in the right, perform the same oscillatory movements, but not too quickly. It is a good idea to do the experiment against a light background and concentrate on the side with coarser teeth. Moving the comb and the opening in opposite directions will "narrow" the teeth and gaps and make them look like the other half of the comb.

Now do the following. On a sheet of paper draw several black circles 2 centimetres in diameter in a line separated by a gap of 8 millimetres.

Take the sheet with the circles into your left hand and the sheet with the opening in your right and start moving them as before. You will see through the opening that the black circles narrowed, turning into ellipses, and the spacing between the circles also narrowed.

A more sophisticated form of the experiment can be carried out using a record-player, set at 45 rotations per minute.

Cut a cardboard circle to fit the record disc. If the cardboard is not white glue some white paper onto it. Separate the circle into 12 sections and draw 12 circles 2.2-2.5 centimetres in diameter at a distance of 1.5 centimetres from the edge. Paint the circles black. Punch an opening in the centre of the cardboard circle and fit it on the record.

In another identical cardboard circle cut 6 equally spaced trapezoid-shaped openings (bases 2.2 and 1.5 centimetres, altitude 2.2 centimetres) 1.5 centimetres from the edge. Make a small hole at the centre of the disc and then slide a small cardboard disc and then the disc with the openings onto a long nail. When you hold the nail vertically, point up, the cardboard disc should rotate freely when set in motion by hand.

And now we proceed to do the experiment. Set the record-player in motion, the disc with black circles being used instead of a record. Hold above the rotating disc the disc with the cuts and rotate it in the opposite direction. Observe through the flashing cuts what takes place on the "record" disc. The black circles have

become thinner at the equator, and compressed into ellipses. By varying the speed of rotation of the disc on the nail, you can attain a distinct and stable image. This simulates the observer approaching the sound source. The "waves" have become shorter and the frequency increased.

And now we will see what will happen with the "waves" if the observer lags behind. The "waves" will elongate, i. e., the black circles will expand at the equator and turn into ellipses lying flat. This is easily seen if the cardboard disc on the nail is rotated in the same direction as the "record". At a certain speed of the disc on the nail (slightly slower than that of the disc on the record-player), you will clearly see that the "waves" will have elongated at the equator.

In order that the transformation of the black circles may be better observed, the "record" disc should be brightly illuminated. The disc on the nail need not necessarily be arranged parallel to the "record"; you may slope it a bit.

$\Delta\lambda$ sodium line shift
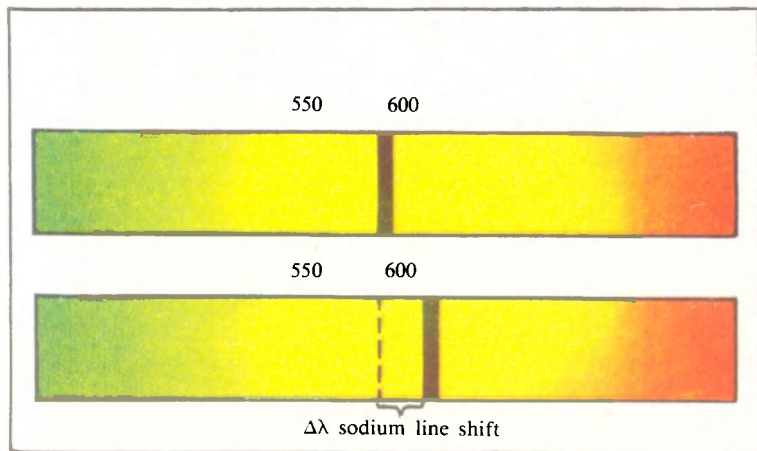
THE MYSTERY OF THE "RED SHIFT". In settling the puzzle of the "red shift", scientists realized that this is a manifestation of the Doppler effect in the realm of light.

If a star, a source of light waves, moves further away or closer to us (understandably at astronomical velocities), then the wavelength of the light it sends out must change too.

Nowadays, astronomers are widely using the Doppler effect not only to find out whether the stars or even the distant galaxies observed are approaching or receding from us, but also to work out the velocity of the movement.

What is the principle of these observations? Solar or stellar spectra show dark lines in strictly definite places.

As you have seen above, the spectra of the Sun or stars have absorption lines caused by various elements, but if the lines, say, of sodium, are displaced to the red, this suggests that the light source is receding. From the amount of this shift we can deduce the velocity of the receding motion.

Our neighbours in space are separated from us by enormous distances. The Universe is several billion light-years across. Recently a new galaxy has been discovered at 8×10^9 light years! To perceive the extent of a light-year remember that in a second light covers 300,000 kilometres. How far will it travel in a minute, hour, day, month, or year?

Everything observed now in the heavens, in the remote regions of the Universe, and everything caught by astronomers with their powerful telescopes, is not what occurs there at this given instant of time. Coming to us now are rays sent out by their sources long, long ago. And it well may be that some of those stars do not exist any more, but we still see them.

THE KITE – A RELATIVE OF AIRCRAFT. Gliding for sport is
an extremely exciting pursuit. Although a heavier-than-air craft, the
glider can soar for a long time high up above the ground supported
by powerful updrafts. Now gaining recognition is a new thrilling
sport, the hang gliding. The craft is a marriage of the kite and
glider. The glider contributed the wings that have here become
a large carrying plane with the fuselage
being replaced by a man's body. Sport-
ing kites, too, can lift a man with
a favourable front wind, in skiing
downhill or water-skiing behind
a speedboat. Whereas sailing boats and
ships require a fair wind to propel
them, kites and gliders need a front
wind for flight.

**Outdoor
Experiments**

In a water or air flow, the pressure is lower compared to that
outside the flow. Let's perform several experiments to see what
occurs in that case.

We will need a thick rubber tube 0.5-1 centimetre in diameter
and a ping-pong ball. Put a clean end of the tube in your mouth,
and bend upwards the other one blowing into the tube. Place the
ball over the open end, as shown. The ball will dance in the jet but
will not stray aside. It is in a kind of air pocket. In this pocket the
air, just as in the entire flow, has a lower pressure with the result
that the atmospheric pressure supports the ball within the
jet.

The experiment presupposes no preliminary training and anyone
can do it at the first go. You need only blow continuously.

Let us now experiment with water. Using Plasticine fix a piece of
string to the same ball, open the tap and place your ball into the
water flow holding the string in your hand. Water will engulf the
ball and it will stay within the flow even if you pull slightly aside
with the string. The ball will hang on the inclined string stretching
it. The fact is that the pressure inside the water flow is lower than

outside and the surrounding air will press the ball into the flow.

The following several experiments should be done at a height. We will have to build a variety of kites to enable us to perform small-scale experiments on parachuting and soft landing without parachute. On those planets where there is no atmosphere a parachute would be useless and for the craft or its part not to be destroyed it must be "softlanded".

Before proceeding to manufacture the kites, let us consider how the kite rises and soars.

When the flat surface of the kite is exposed to a fast air flow, or just wind, and slightly inclined in it, the air strikes the plane producing the so-called lift which is responsible for the kite soaring. Without wind, the kite will not fly. To fly in a faint wind, a kite requires a lift produced by an artificial air current. It is necessary to pull it up by running and if there is more wind above to support the kite you can then stand on the ground and control its flight. Aeroplanes are powered by engines so that the artificial flow is
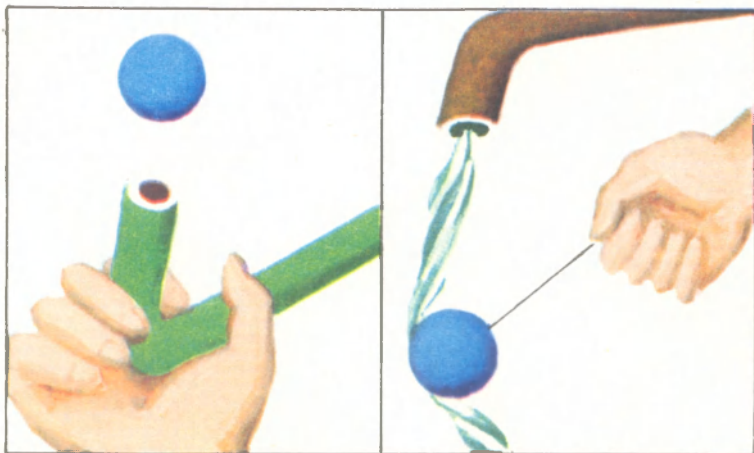
created first by the plane moving fast along the ground, and then
flying in the air.

VARIOUS FORMS OF KITES. We first construct the simplest
kite. The materials required are paper and balsawood laths. The
thinner the laths, the lighter will be the kite, provided, of course,
that its strength is not impaired.

Glue a 65×45 cm frame with diagonal laths glued, and tied up
with a string, as shown. It is a clever idea to wrap all the glued
joints with several layers of string for added strength. Next take
a sheet of thin, but strong, paper and glue it to the frame and dia-
gonal elements. The sheet should be somewhat larger than the
frame.

Wrap the edges of the paper round the laths and glue them. For
the kite not to be too heavy, it will be sufficient if the glued edges
are only 1-1.5 centimetres wide.
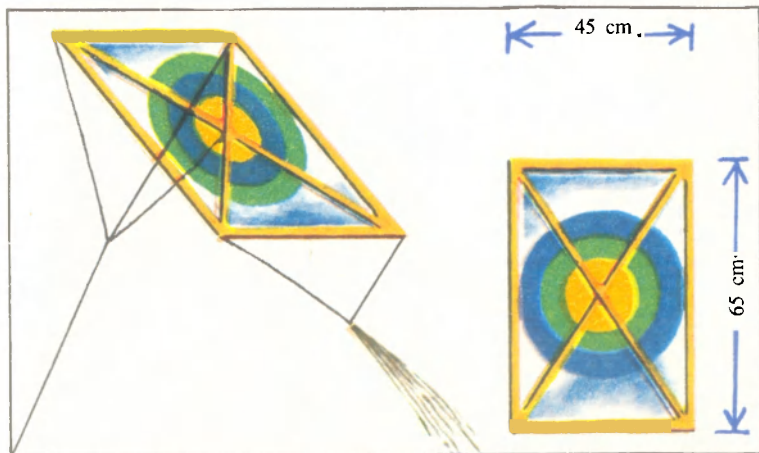
Tie some strong thin string to the two corners of the narrower side of the kite. The loop, when taut, should form an isosceles triangle with 39-centimetre sides. At the middle of the criss-cross tie another piece of thin string about 33 centimetres long and tie the loose end to the middle of the loop. To this connection tie some string wound on a reel or a wooden board. At the opposite side tie to the corner a tail, 2-3 metres long made from ribbons of fabric. This is required for the kite to be stable in flight. After a test flight you will see whether the tail should be made shorter or longer, or maybe some weight should be added at its end. It may be that you will need to adjust the tail for each flight of the kite, this may also depend on the wind.

Now that everything is ready, wait for a suitable wind. A gentle breeze may be insufficient to send the kite up, on the other hand, a strong wind may break it up at once.

It generally takes two people to fly a kite. One holds it and runs against the wind, the other holds the reel. Having accelerated, try to let the kite go. If the wind keeps it up, ease off gently the string. By paying out more string away you can make the kite gain height. When it has climbed 100-200 metres, the kite will soar in the air.

For the enterprise to be a success, the connecting strings on the kite should orientate the kite's plane to be about 30-40° to the horizontal. This is also helped by the tail.

Another important rule: never fly kites near electric lines, trees, and other structures, but only in the country, in some open place.

Now that we have learnt to make and fly a simple kite, we will try and make a box structure that is more stable in flight. This kite does not need a tail, its stability being provided by its shape.
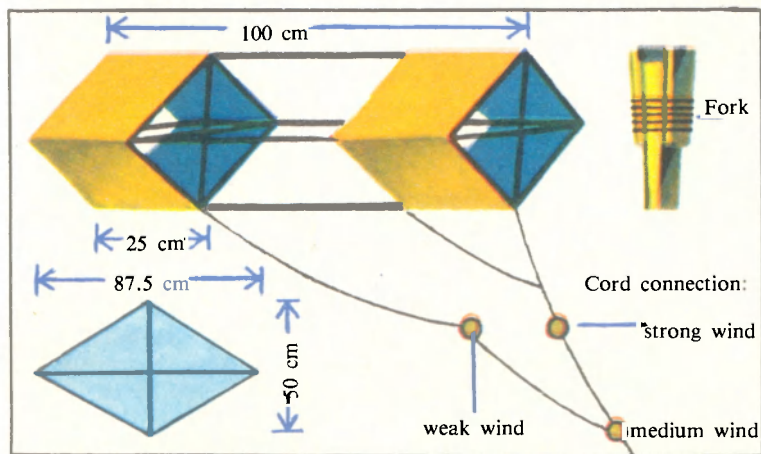
It is also made of balsawood and some calico fabric but instead of string we will use nylon fishing-line, as it is light and strong.

Cut four balsa sticks 100 centimetres long and with a cross section of 8×8 millimetres. These will make the longitudinal ribs of the kite frame, the longerons. We need four more sticks: two 50 centimetres long and two 87.5 centimetres long, both 8×4 milli-

metres in cross section. These will be the transverse elements of the
frame and at their ends make "forks" to receive the longerons. Our
kite will be made in sections to make carrying it easier as you may
need to take it into the country to fly. The kite is readily
assembled.

The forks are made of short sticks 8×2 millimetres in cross sec-
tion. Before you tie them with strong string to the transverse ele-
ments glue appropriate places with balsa cement.

Assemble the frame thus: install the transverse elements at the
ends of the longerons and tie their intersections with string. So that
the frame does not fall apart, wrap it in two places in the middle
with twine. And now it is the turn of the carrying planes. Measure
the perimeter of the frame rhomb and make two calico ribbons 25
centimetres wide to go round it. The edges of the ribbon should be
tucked under and worked with a sewing machine. Fasten one end
of the ribbon onto the end of one of the longerons (preferably on
the stick at the acute angle of the rhomb) with small nails or draw-

ing pins. Glue with cement those places of the longerons with which the fabric will be in contact, and stretch the ribbon onto the frame. Tighten the fabric and fix the end of the ribbon with cement and nails. For the fabric to be taut, it should be stretched when wet. After it has dried it will fit the frame tightly. Repeat the procedure with the second ribbon. If necessary, realign the transverse elements to rectify the kite's shape.

The fabric can also be applied in another way, e. g., by sewing special "pockets" where the fabric is to be fastened to the longerons, for these latter to be inserted into them.

The flying properties of the kite will be determined by the quality of fabrication. A "bridle", made from the thin strong string, should be attached to the longeron at the obtuse angle of the rhomb. Attach one end of the string to the extreme end of the longeron and tie the second end of the string (one metre long) to the stick where the internal edge of the back ribbon is located, i. e., 25 centimetres from the kite end. Bind another piece of string to the stick at the inner edge of the front ribbon, i. e., 25 centimetres away from the front end of the kite. Tie the second end of the second string to the first string 25 centimetres from the first string's end.

The cord should be tied to the "bridle" in a way that depends on the wind intensity. The stronger the wind, the closer to the connection of the two strings should the cord be tied. You should work it out by flying your kite. The details of the structure are given in the accompanying figure.

The box kite has more carrying planes than the simple structure and it can be compared to a biplane, a plane with two pairs of wings.

When you accumulate some experience in evaluating the wind strength and in flying the kites, the following amusing experiments can be done which need a great height. High up a kite behaves in a more stable manner, as the wind there blows more steadily. Close to the ground the air flow suffers from eddies, therefore you should strive to send the kite as high and. as soon as possible.

"AIR MAIL". This is the simplest of the kite experiments and can be done with any form of kite. Cut a disc, 20-30 centimetres in diameter from thick paper, and cut a hole at its centre and then cut along the radius. Next, from the same paper, roll up a cylinder 5-8 centimetres long, but less than a centimetre in diameter. When you fly the kite ask your companion to hold the cord, and having unfolded the cylinder slide it onto the cord and restore it to the cylinder form again. Onto the cylinder, fasten the paper disc, having first overlapped the edges and secured with a safety pin, to produce a paper cone that fits tightly onto the paper tube. Move the structure up along the cord for the wind to catch it and transport to the kite. It will stay up there as long as the kite is flying.

PARACHUTING. It is well known that when astronauts return to Earth from a space mission, in the final stage of the landing the capsule is parachuted.

From thin copper wire, no more than 0.5 millimetre in diameter,
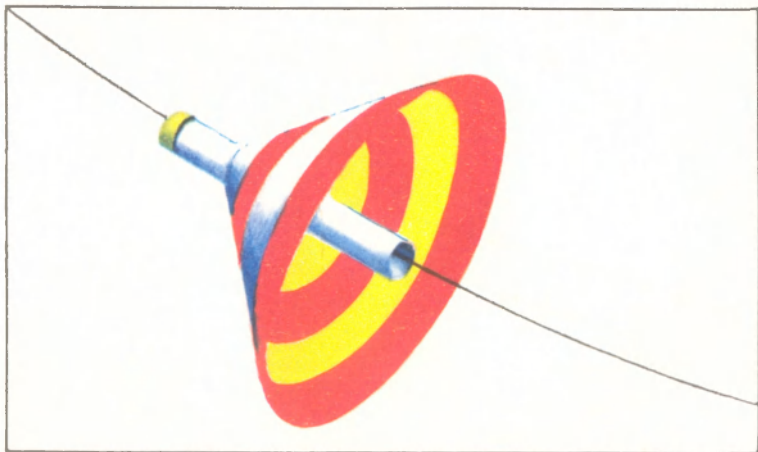
make a frame so that it can be readily suspended on the kite's cord
by bending the ends into hooks. The hooks should slide freely
along the cord. Along the frame and into additional hooks, pass
a piece of copper wire (we will call it the "movable rod"). Bend the
end closer to the kite into a free hook around the cord several cen-
timetres ahead of the frame. Bend the other end of the movable
rod by 180° after it has been passed through the hooks of the mov-
able frame. To this end we will suspend our "landing capsule" (a
rubber ball with a small parachute, made of fabric, tied to it). For
the parachute not to fold, make for it a rim of a thin wire. On the
top of the parachute cupola cut a small hole.

Construct a "stop" (a piece of stick flung over with two cord
loops) on the main kite cord about a metre away from the kite.

When you are flying the kite, suspend to the cord the frame with
the parachute and "landing capsule", and check that all the ele-
ments will move freely, and the parachute be fixed securely to the
hook of the movable rod (see the accompanying figure) when the
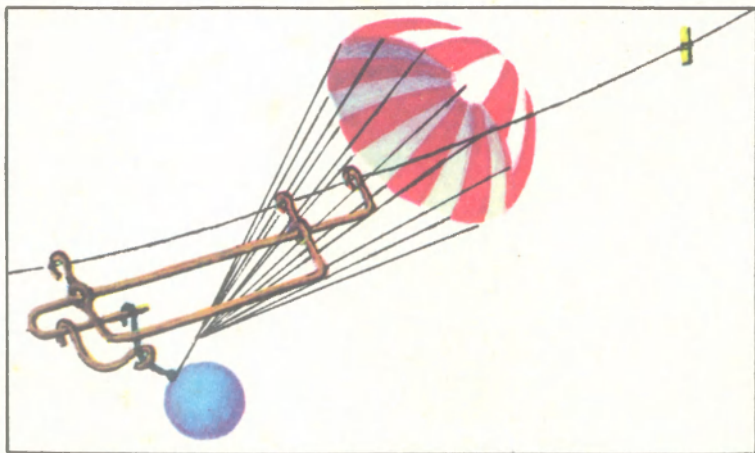
wind carries it up the cord. When everything has been checked, you may let the system go. The wind will pick the parachute up and the system will slide up the cord. The front end of the movable rod will reach the stop near the kite, and the rod will stop. The frame, however, will slide a little further, drawn by the parachute. The lower end of the rod will then be dislodged from the frame and the loop on which the "landing capsule" is suspended will slip off the hook on the movable rod, the parachute will then break loose and, together with the "landing capsule", will descend to the ground. The automatic device, having performed its task, will now have lost the parachute that drew it up and will slide back down the cord into your hands.

This experiment may be a failure at first as everything depends on the wind intensity. See to it that all the connections are loose, and the system is sufficiently light. It may well be that the movable rod will have to be remade from some thicker wire or you may need to change the size of the frame. This experiment should be approached with imagination, using your initiative and wits. Do not let the first failure upset you. Await a suitable wind and repeat the experiment.

SOFT LANDING. For the "landing capsule" to land softly we will make use of a jet engine to hold the speed down.

Our experiment will be an abstraction because on Earth we have an atmosphere. Let us imagine that we are not on Earth, but on Mars or Mercury or the Moon and we need to use the jet engine for breaking.

Suspend the "landing capsule" with a jet engine to the hook of the movable rod of our system used earlier. And to the frame tie the parachute, also used in the preceding experiment (we will need the parachute to take the "lander" up).

In this experiment the lander will be a Plasticine ball, with a thin rubber tube running through it and the role of the jet engine will be played by a balloon. Insert one end of the tube into the balloon
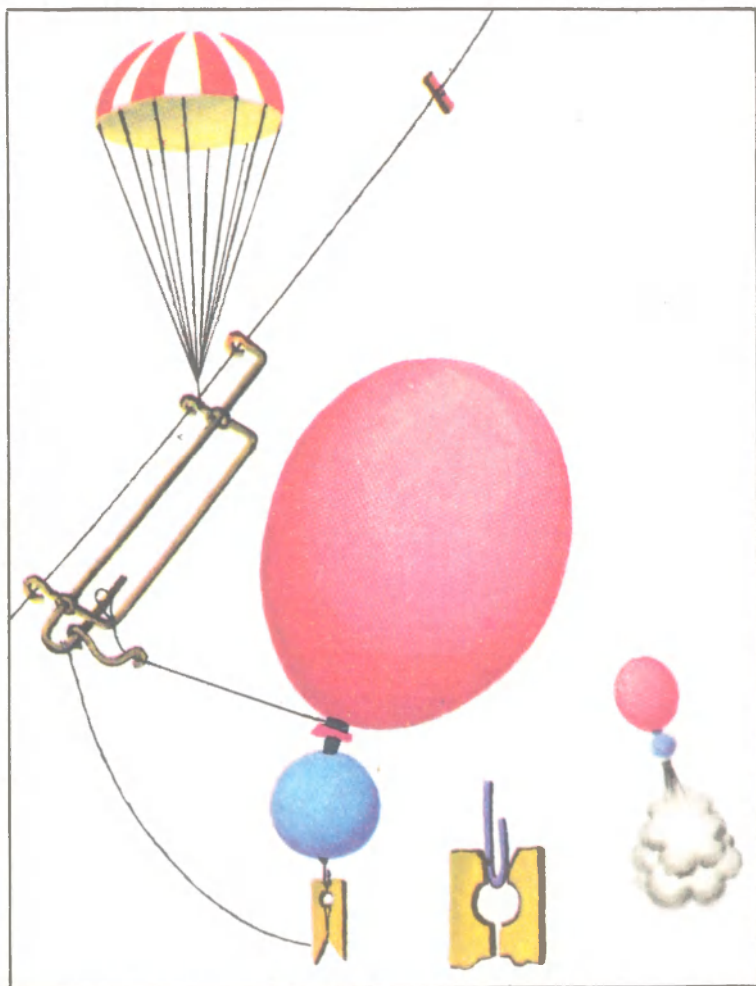
and wind the connection with a string. Clamp the other end shut after you have blown the balloon up. Tie to·the clamp one end of a piece of string and tie the other end of the string to the movable rod. The inflated balloon ·with the lander is often suspended from the end of the movable rod in much the same way as the ball in the preceding experiment.

Once the kite is flying, everything is ready and the wind can take the system up. When the end of the movable rod strikes the stop, the lander will slide off the rod hook and begin to fall down, then the string will snatch the clamp. The balloon with the lander will continue to fall but the air from the balloon will be rushing out through the tube thrusting the lander up, with the result that the vehicle will softland. Admittedly, the experiment is not "pure" as the landing has been affected by the surrounding air, but still the show should be spectacular.

For the best results check all the elements of the experiment beforehand. First, be sure that the wind is strong enough to transport the device up the cord. Second, see to it that the clamp does not leak and comes off easily, when required.

Practice all the stages of the experiment on the ground under favourable conditions.

THE DOCKING OF KITES. Today, "docking" is a household word. It immediately brings to mind two spacecraft coming together in space. This is an exceedingly difficult manoeuvre, that calls for great accuracy in launching the ships, and great skill and fast reactions from the crews.

Railway vans, for instance, are also docked in a way, i.e., coupled. This is a rather simple operation. They roll together guided by the rails and have no other alternative but to couple.

In space, in a three-dimensional situation, the coupling is quite a problem.

We will try to dock, or rather couple, two box kites soaring in air. The manoeuvre is not always a success because a lot depends

not only on the quality of the kites, and the skill of the operators, but also on the wind.

During the experiment it is very important for the wind not to be gusty. The kites will then be able to "stand still" in mid-air. To be sure, the dexterity and gumption of the participants also play a part.

The experiment requires two teams each with three people, and a "controller" to guide the experiment.

What else is required?

Above all, you need two identical box kites. Each of them will be flown using two cords tied to the bridle at the same point. The connection point should be carefully selected depending on the wind intensity.

Next, we need coupling rigs. At the back of one of the kites tightly tie a semi-circle made from a withe (a willow twig), debarked and dried bent into a hook.

Attach a withe loop as above to the longeron of the front section
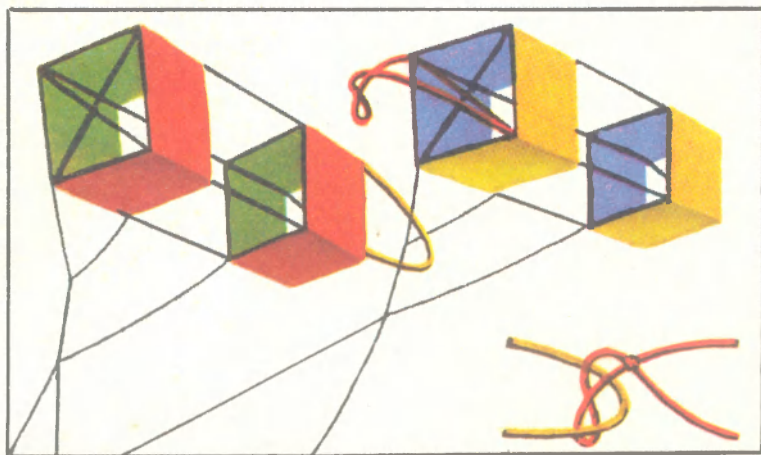
of the other kite. In this case the withe should be a bit longer than
the other kite's. Bend the withes gradually and when you have pro-
duced the loop for the hook, wrap the crossover point with string,
bend the loop a little and tie the withe's ends to the longerons. By
using string and light auxiliary sticks shape the hook to your satis-
faction. After the semi-circle and hook have dried well, these may
be taken down for easier transportation and reinstalling before fly-
ing the kites.

The kites should be flown one after the other some distance
away from each other. Each kite need to be attended by three peo-
ple: two to hold a cord each, and one to hold the kite overhead.
The kite with the semi-circle should be in front, and behind it the
kite with the hook. When the kites have reached the same height,
bring the rear kite up to the front one, the controller observing the
approaching kites from a distance and giving clear commands. If
the first approach is not successful, the front kite should be taken
forward a bit and the manoeuvre repeated.

If one cord becomes entangled with another in the air, do not try
to disentangle them while the kites are flying. Bring them down,
disentangle them and then fly them again.

It may well be that when the kites have docked their flying prop-
erties will change somewhat and it will be necessary to land them
speedily.

Flying the kites in or before a thunderstorm must be avoided.

ROBOTS COME FIRST. Before manned interplanetary mission can be made possible, robot spacecraft are sent, because we cannot risk a human life. Recorded history knows, however, many examples of scientists and inventors who risked their lives for the benefit of science and ideas. But this was a calculated and not a reckless risk. Such risk was taken, for example, by the early airman Konstantin Konstantinovich Artseulov, who at the dawn of aviation, in 1916, worked out and tested the procedures for recovering a plane from a deadly spin. In those years many a pilot died because of the general lack of experience in handling the plane in a spin. The plane would get out of control and fall, spinning to destruction. Artseulov set out to solve the problem of handling this fatal situation by recovering the control of the craft and landing to safety. He developed several tricks which, in his opinion, ensured a safe recovery from a spin.

## Planetary Roving Vehicles on Your Stand

Granted, he took risks but calculated ones. Artseulov was more than confident that his calculations were correct. So, he had gained height and sent his plane into a spin. Applying his procedures, he recovered the craft from the dangerous manoeuvre. To see that this is not just chance, he repeated his experiment. Ever since, all airmen have been using Artseulov's experiment to save so many lives.

Thus, whilst we cannot be dead sure that visits to the planets of the solar system are safe for the health and life of human beings and whilst there are no guarantees of human explorer returning safely to Earth, robots will do the job of exploring the planets. They are successful in performing their tasks and need not be returned unless the mission involves the transporting of some samples to Earth. For example, the lunar soil samples were brought to Earth by the Soviet automatic stations. The earthbased scientists

Automatic universal
research station
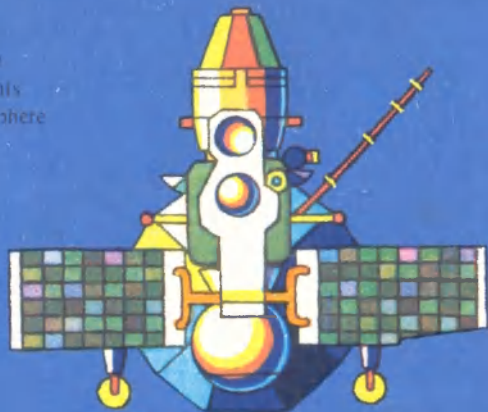"Intercosmos 17"
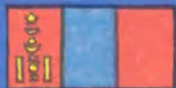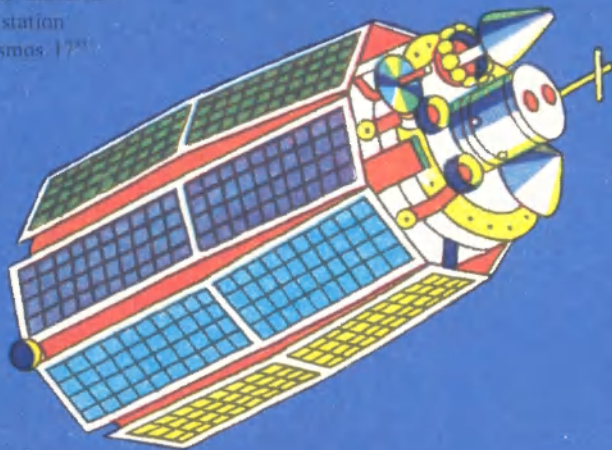
INTERCOSMOS

Research programme
"Intercosmos"
Bulgaria, Cuba,
Czechoslovakia, DDR,
Hungary, Mongolia,
Poland, Romania, USSR,
Vietnam
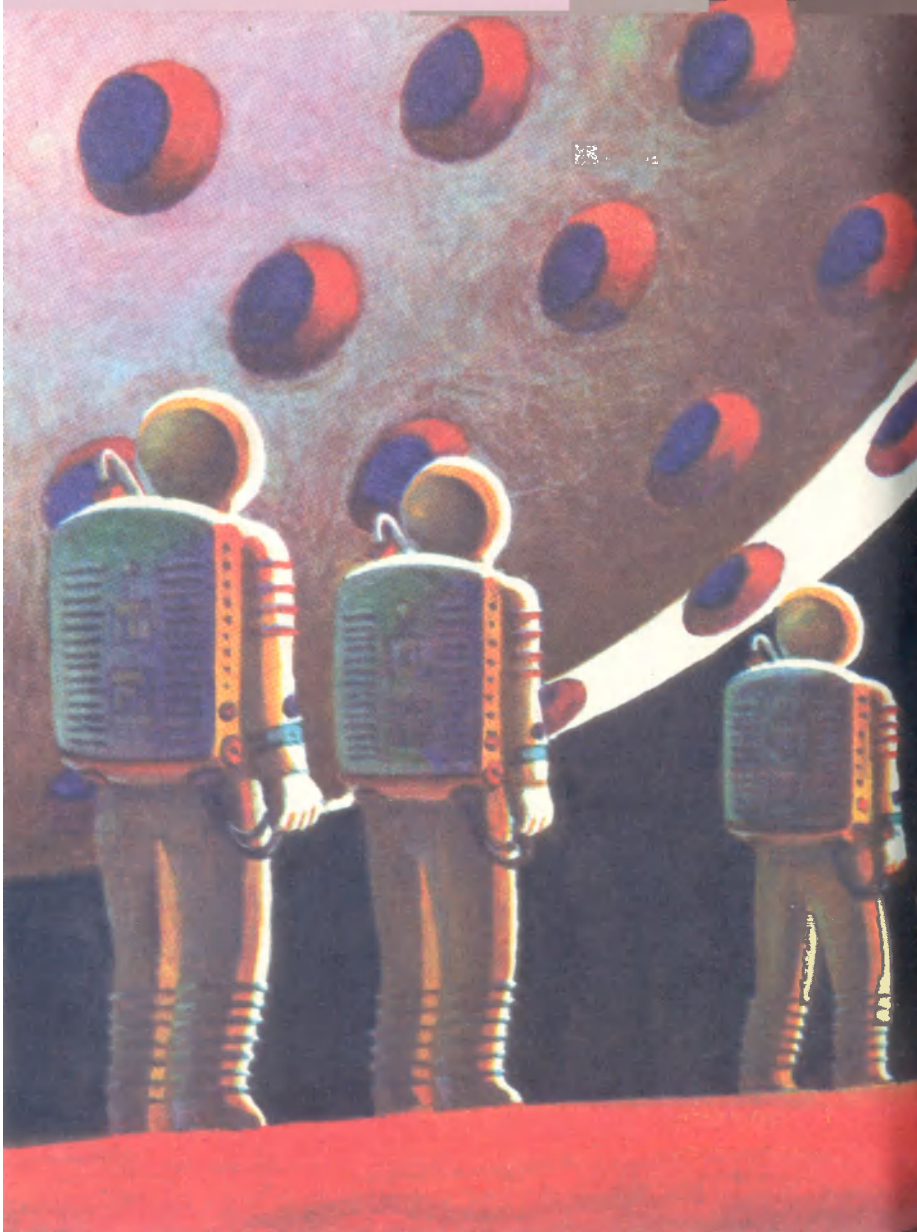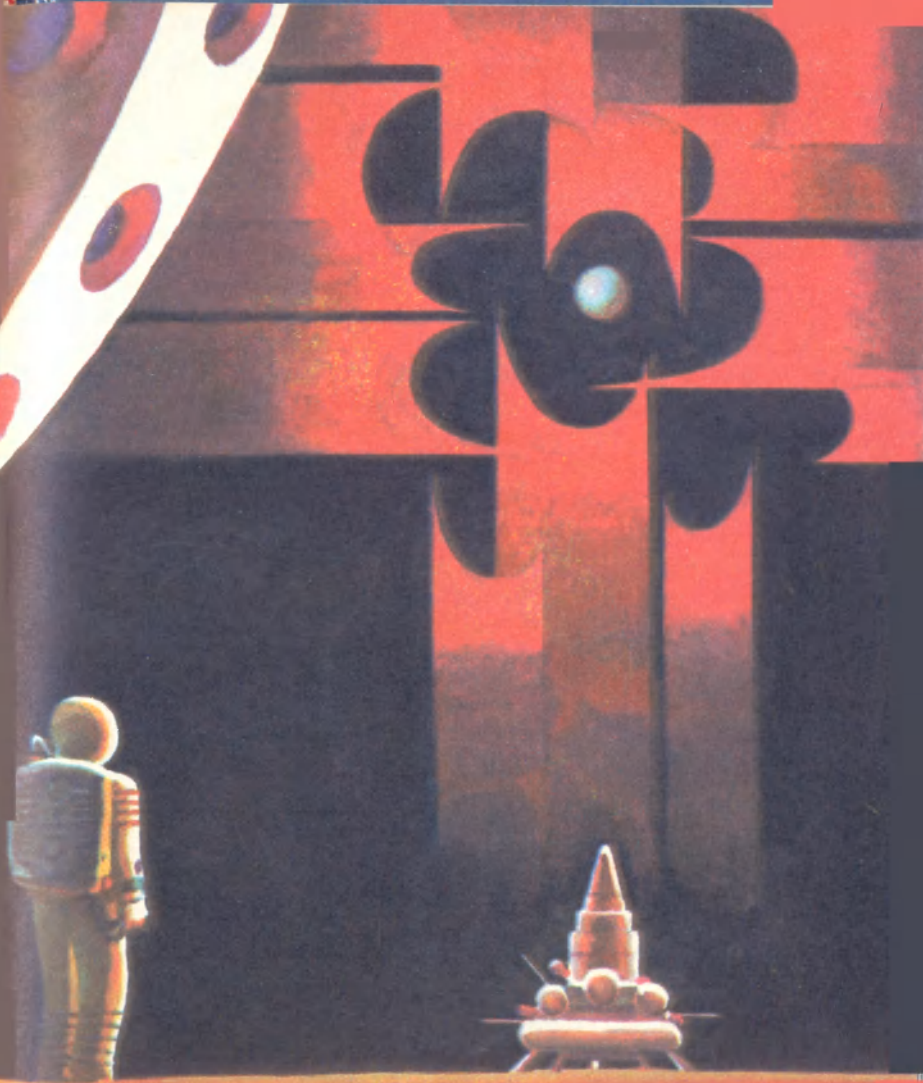
A glance into the future.
First people on the planet Mars

Planetary probe "Venera 5" made direct measurements of Venus's atmosphere
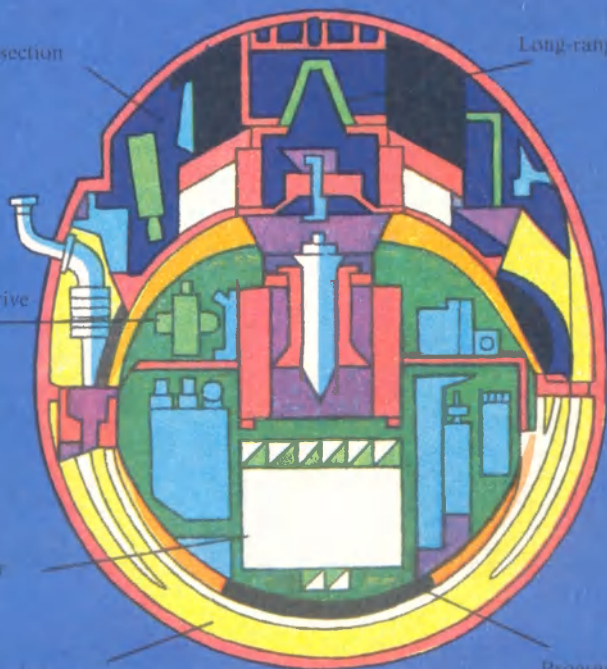
Parachute section

Long-range antenna

Antenna drive

The "Venera 8" capsule that softlanded on Venus

Transmitter

Thermal insulation

Programmer unit

and the programmed robot vehicles are linked by radio and the communication is two-way. From the Earth, radio signals are beamed as a train of coded pulses to control the devices and systems on board the ship, and back to Earth messages are sent in the same language of robots. Here they are decoded by special decoders.

One of the most important means of exploring the Moon are the self-propelled mooncars which on command from the Earth move about the lunar surface, carry out observations and send the results to Earth.

The world watched the prolonged mission of the Soviet *Lunokhods*. They have covered dozens of kilometres over the Moon's surface and reported, in the coded language of radio signals and TV transmissions, what they had "found out" and "seen".

Another Soviet robot spacecraft has brought back from the Moon core samples of lunar rock and soil to give sicentists a rare opportunity to study lunar material.

Automata are excellent workers. For decades to come they will keep reconnoitering the way for manned interplanetary flight and safe return to Earth.

But meanwhile, man ventures into terrestrial space accomplishing what cannot be done by artificial satellites, studying the feasibility of man's prolonged stay in space, testing the measures to combat the deleterious effects of weightlessness and a prolonged stay in confined quarters on the organism.

We will make several automata to gain a rudimentary understanding of how real robots function. Among them there will be planetary roving vehicles (PRV) too.

The models to be constructed are, of course, a far cry from the true structures. Rather, these are not even models, but moving stands, individual components, and parts which give some idea of a few of the principles of robots and remotedly-controlled devices and systems.

In designing real PRVs scientists take into account the real con-

ditions of the work to be done: surface relief, availability of an atmosphere, temperature variations, predicted humidity of the atmosphere (if any), and a host of other physical and chemical conditions.

A SIMPLE MODEL PRV. Given below is just a brief description of an automatic vehicle for the other planets. First, it will give you an opportunity to show your enterprise and invent and improve something. Second, if we advise you to use specific materials that are not available, you will need to replace them.

To begin with, we will make an extremely simplified model of a planetary vehicle, a three-wheeled self-propelled device steered from a distance. For the impulses needed to control the model we will use water in a pipette.

Cut from plywood a round platform about 12 centimetres in diameter. On the top we will isntall a mechanism to power and steer the apparatus, and below we will put an undercarriage with three
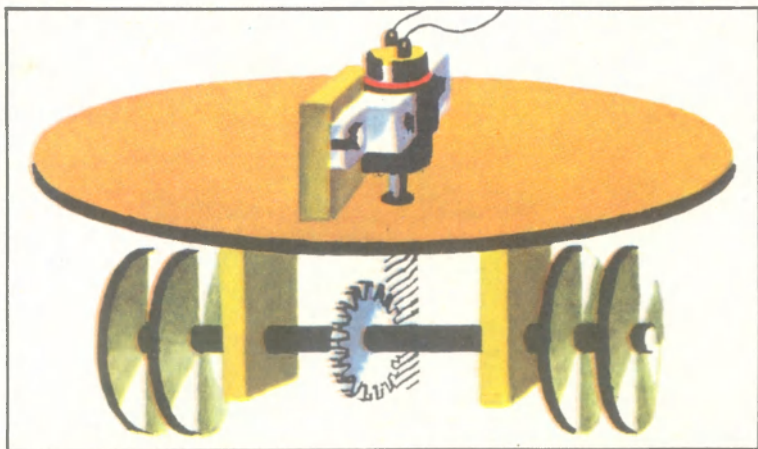
wheels: two rear driving wheels and one front steerable wheel. *Lunokhods* that have successfully roved about the Moon have eight wheel units, all of them driving.

For the wheels, use plastic reels for amateur 2×8 mm cinefilm, they are about 5 centimetres in diameter. Of course, such wheels can only roll over smooth floor, but we are now only interested in the principle of control.

Onto an axle made of a tube or round stick (a pencil will do) fix the largest cog of an old alarm clock, having removed it first from its original steel axle. Remove the steel axle carefully using a pair of pliers and a screwdriver, removing the spring plane first. If you are using a pencil, then cover the middle tightly with some metal (you can mould it from tin) or short plastic tube, and then put the cog onto it. Beneath the platform, fasten with small screws two "bearings" (balsawood props with openings to receive the axle with wheels). The platform should have a hole drilled into it near the cog. Through the hole, a worm cog fitted onto the axle of a micro-

Spring   Tiller   Stop Spring Safety pin
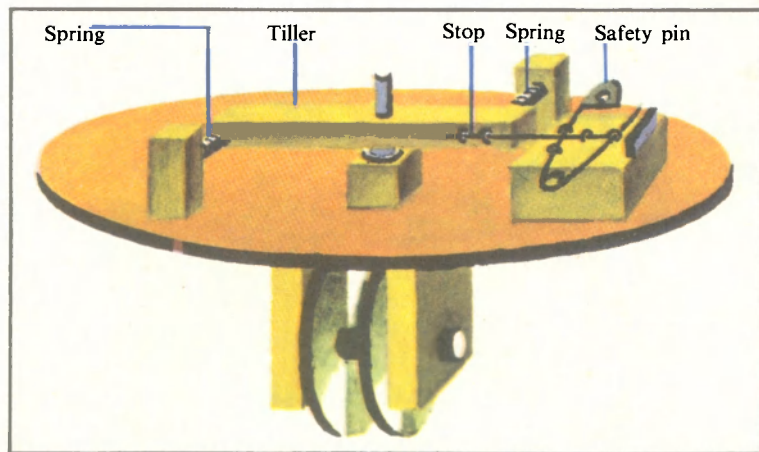
motor, arranged on top of the platform, should be passed. The motor axis must be normal to the platform. Micromotors come in a variety of types, all being powered by a dry cell. Purchase a motor with a reducer to lower the rotation speed and the worm can be salvaged from a broken toy. Make sure the worm and the cog mesh adequately. If necessary, use a file to make the parts fit better. Finally fasten the motor to the platform and proceed to make the steering mechanism. To simplify matters, it will only turn to one side with the position of the steering wheel fixed, i.e., the car will move in a circle.

Use three pieces of balsa to make a steering fork and fix a short wooden axis to it. Fit a wheel onto the axle by passing the axle through the bearings and the hole in the wheel. Drill a hole through the platform and a strut glued to the platform. Slide a metal or plastic washer onto the steering column to reduce the friction between the fork and the platform, and attach a wooden lath to the steering column. In the maritime language this is called

Contacts

Support Micromotor Support

Sugar Dry cell Sugar
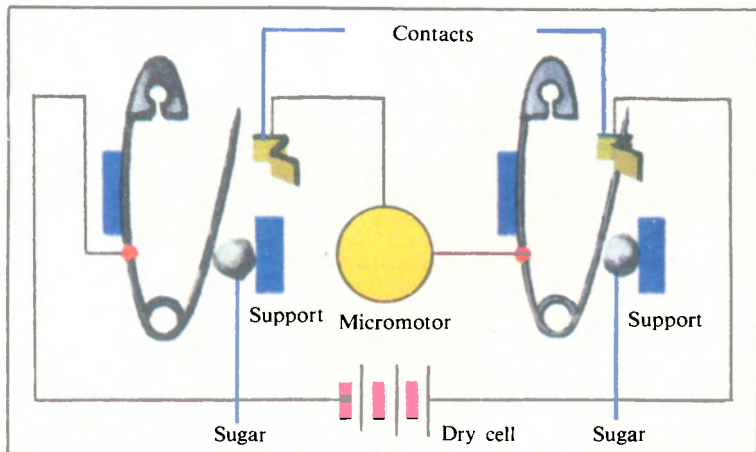
a tiller. The tiller ends must be stretched by springs in the opposite directions. For the steering mechanism to be in the position "forward", turn the tiller, having stretched the springs, and fix one of its arms by a piece of wire that as necessary may be removed to liberate the tiller end. The action of the springs will then turn the steering mechanism and the car will move in a circle.

Next, install a dry cell on the platform and make the necessary connections.

Then mount two make-and-break mechanisms onto the platform to guide the electric current from the dry cell to the micromotor. Our make-and-break mechanism consists of a safety pin and a contact. The first mechanism, designed to start the motor, uses the contact consisting of a curved brass plate and the needle of the safety pin. The pin and brass plate should be so arranged that the needle makes contact with the brass plate when fully open. Compress the pin a bit and the contact will be undone. Insert a small piece of sugar between the needle and a special support constructed
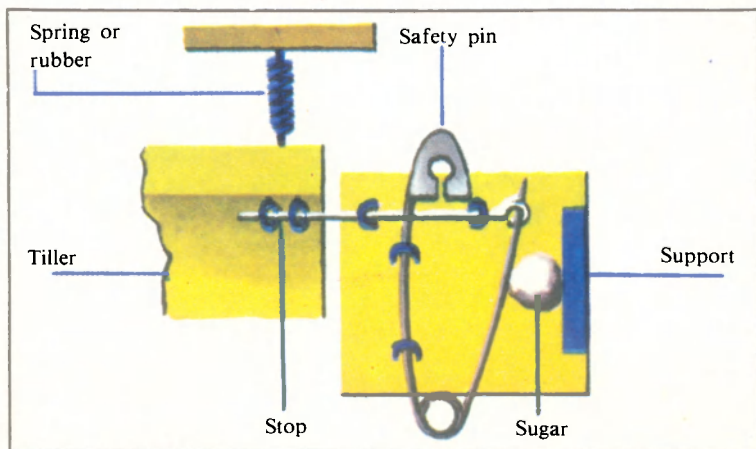
for the purpose. The safety pin is a good spring, striving to unbend fully, but the piece of sugar prevents it from doing so. But if we add a drop of water on the sugar, it will instantly crumble, the pin will expand and close the contacts of the motor. The second mechanism stops the motor. A drop of water added to the other piece of sugar lets the other safety pin open and in so doing breaks the supply circuit of the motor.

Turning to the steering mechanism, near the wire (stop) preventing the tiller from turning install one more safety pin and a piece of sugar so that its needle touches the loop at the stop end. When the "water pulse" wets the sugar, the pin will open and shift the stop and the tiller will turn the steering mechanism under the action of springs.

You may, of course, make other devices controlled by water signals that substitute for radio signals.

Granted, these are very simple devices disigned only to illustrate how commands can be carried out, such as start, turn, and stop. In our case we have three commands (three pulses) and three operations.

For each fresh run, the device has to be recharged and prepared to repeat the programme.

If desired, the vehicle can be supplied with cardboard body, into which tubes, going to the places where the "water pulses" are to be dropped, can be inserted. Instructions at the outer ends of the tubes ("start", "turn", and "stop") will help us.

SEVERAL AUTOMATIC UNITS. If the idea of creating a more refined distance-controlled planetary vehicle has some appeal for you, then you will need to become acquainted first with some automatic units to replace springs (safety pins). It is more convenient to handle these units on a small stand, a smooth board on which you could assemble and adjust your units before installing them into the model vehicle.

We begin with the unit to start and stop the motor. On the stand set

up a small strut with a small stick attached to it (see the figure).
The stick should easily rotate about a horizontal axis and at the
stick ends there should be two platforms. Under one of them
arrange a copper contact perpendicular to the platform. If the re-
spective arm of the stick is lowered to contact the stand, the contact
should enter an M-shaped second contact made of a narrow brass
or copper strip. Connect the fixed contact to one of the poles of
the dry cell and the second to the strut through the micromotor or
a lamp. Pass a wire from the strut, along the stick, to the contact
installed under the platform. Under the platforms, when the stick is
horizontal, install vertically two tubes. One should reach the plat-
form with the contact, and the end of the second one should be
high enough so that the second platform would reach it when the
stick is turned and the contacts of the other end of the stick are
closed. Perhaps, you have surmised how the arrangement will
function.

We will need some steel balls. Their diameters will predetermine

Micromotor   Micromotor
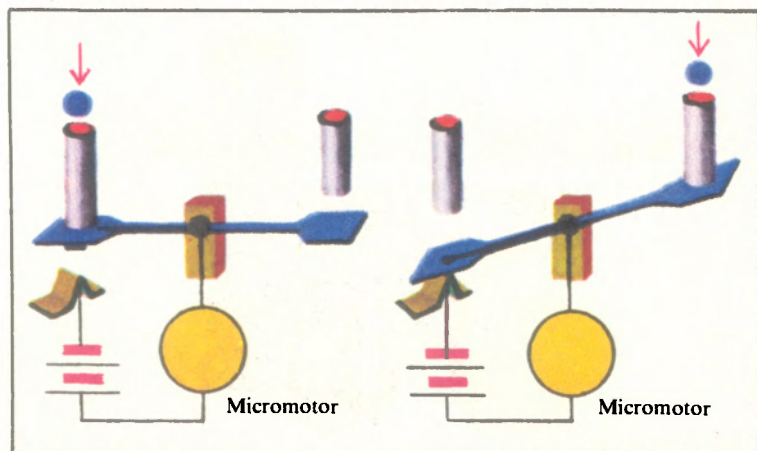
the stick length and tube diameter. The tubes are designed to drop the balls, our command impulses, where necessary.

When everything is ready and all the required connections are made, we can proceed to test our device. Initially the stick should be horizontal. Drop a ball into the tube above the contact end of the stick. Striking the platform, it will move the end of the stick down, the contact will close and will remain so due to the M-shaped clamp at the contact energizing the micromotor or the lamp. Now drop a ball into the other tube. The contacts should be adjusted so that they disconnect when a ball strikes the second platform readily and connects reliably. The ball falls, the rod turns, the contacts disconnect, the motor stops, and the lamp, if it was switched on, goes out.

The radio signal that with the appropriate apparatus makes necessary connections and disconnections is replaced here by a ball.

To help the rod rotate easily and without swinging, use small washers (these can be domes of plastic or drawing pins with

Rubber
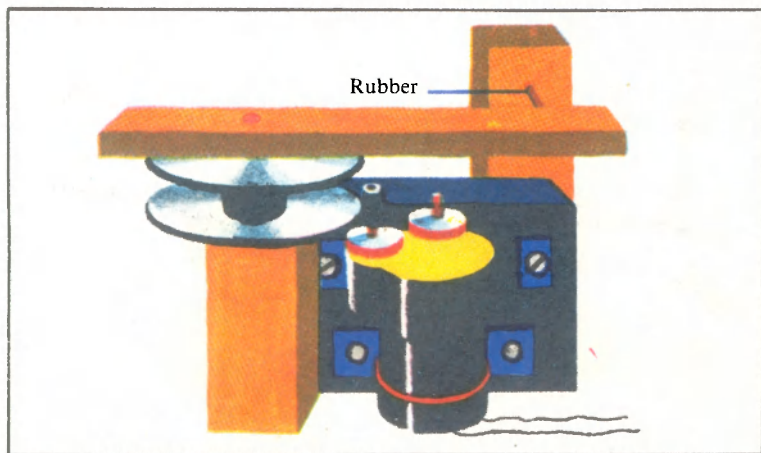
pointed parts filed away) slipped on the axle.

Now, we will be concerned with the steering mechanism. It can also be assembled on the stand. Place the board (stand) on two supports several centimetres high, and drill a hole in the board for a round wooden rod 6-7 millimetres in diameter. Cut a piece of wood 2-3 centimetres thick from a board, but before cutting it drill a hole in it with the same diameter as the hole in the stand. Glue the piece to the stand so that the holes match, by using a wooden rod inserted into both holes. Make sure that the rod does not get stuck in the holes. This rod will be the axis of the steering mechanism. Wait for the glue to dry, then insert the axis into the holes and push a plastic film reel onto it. The axis end should protrude a little from under the reel. Attach a lath about 10 centimetres long to it. Attach two rubbers that are not very stiff to the lath end, the tiller. Secure the other ends of the rubbers at some distance from the tiller by binding them to the struts. The axle should be free to rotate in its bearing, and the rubbers should
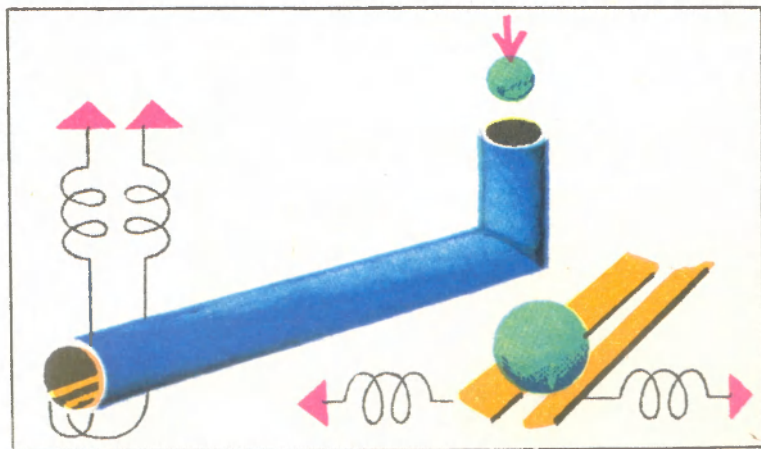
return it to the initial position after each turn (no greater than 40°). Near the reel install the micromotor with the reducer. Its axis should be vertical and the end of a rubber nipple fitted onto it should touch the reel edge. When energized, the reel will rotate, and one of the rubbers will stretch, the other slackening. The motor should trip out as soon as the reel has turned by 40°, the rubber thereafter returning the mechanism to the initial position.

Instead of a rubber band, we can fasten to the axis a spiral spring to return the reel to the initial position. Why do you need this? When you ride a bicycle and want to turn, you turn the steering bars and then returning them to normal, of course, since you do not want to circle in the same place. Here too, after the turn the steering mechanism should be brought back to the initial position.

Now we make the contact switch; it will enable us to turn the apparatus in the required direction. Commands will be transmitted by "impulses", i.e., balls.

The underlying idea is that the contact switch only operates when along a 10-15 centimetre long tube rolls a ball. Within the space of these several seconds the tiller should turn. The tube is made of thin cardboard, its diameter being about 2-3 millimetres larger than that of the ball. Select a round rod to suit the diameter of the tube. This will be the template to make the cardboard tube. While bending the cardboard, mark with pencil the places where to glue, cut off any excess material and unfold the tube. Then cut two narrow strips of metal foil and glue them to the unfolded tube. Prior to gluing place under a strip a thin copper or blass plate with a piece of copper wire soldered to it. The foil strips are glued so that the gap between them is around 2 millimetres and other sides of these strips do not come together when the tube is made. Now roll the tube using the template and glue it together. The tube is installed almost horizontally. Perpendicular to the elevated end attach another tube of the same diameter, but now without any foil patches. You have thus obtained a "knee". A ball launched into

this knee will come to the foils, make the circuit, and roll on further. The circuit will be made as long as the ball stays within the knee. When it leaves the foil the circuit opens. There should be two such tubes: one for the right turn, the other for the left.

The drawing shows the way in which the wires are to be connected. To turn the vehicle to the right in motion, just drop a "ball-impulse" into an appropriate knee, the ball closes the foil contacts and rolls down over them. This starts the micromotor and turns the tiller with the result that the vehicle turns to the right. Once the ball has come out, the tiller motor stops, the rubbers bring the steering mechanism back to normal and the planetary vehicle will travel on till another command. When you want to turn the vehicle to the left, drop a ball into the left tube. This again will close the contacts, switch in the second dry cell to feed the contacts of the tiller motor, but now in the opposite direction because of the change in polarity. The motor now rotates in the opposite direction and the steering mechanism turns to the left.
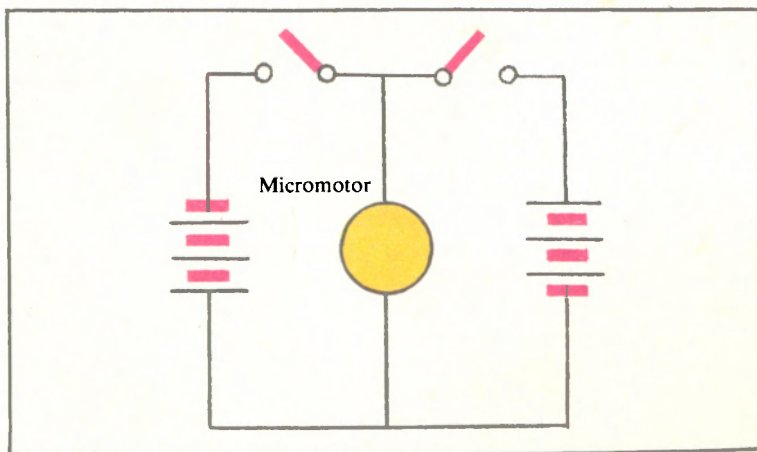
Micromotor

The circuit diagram shows that the model has two dry cells to control the tiller. Adjust the steering mechanism at the stand. The rubbers should not be too stiff so that the micromotor could easily stretch them and you could regulate the duration of the motor operation by placing pieces of paper into the tube outlet or by changing the tilt of the tube.

After all the necessary adjustments have been made, you can proceed to make the planetary vehicle proper. And after you have assembled it you may need to make some additional adjustments. It might appear, for example, that one micromotor is not enough, so that you will need an additional one. Certainly, in actual practice design engineers make their calculations and drawings beforehand, but they also construct a prototype to check if everything has been taken into account and provided for. But you will have to use the materials available and proceed mostly by trial and error.

MORE SOPHISTICATED PRV. This vehicle will be on six wheels, the wheels being plastic reels for cinefilm. Two wheels slipped together on an axle will be driving ones; other two, the steering wheels, and the two interim wheels will be free running. Should your motor appear to be too weak, you will have to install another motor to drive these intermediate wheels. '

The driving axle, with its wheels, is connected to the motor through a worm gearing, as in the earlier model. If a worm is not available, use a small cog of an old alarm clock. The micromotor should be a gear type. Install it on a turntable, with a fixable bracket, to simplify adjustment of the meshing of the "worm", which is fitted on the motor axle, and the cog of the driving wheels.

The steering wheels are installed on a turning bogie made of pieces of lath and plywood. To the middle of the bogie fasten the steering column slipped through a hole in the platform. On the platform glue a wooden bush, and above it install the steering wheel and the tiller made earlier at the stand.

On the top of the platform arrange and fix the dry cells and the tubes. Connect the dry cells via the contacts to the micromotors.

After you have finished the work, test the planetary vehicle in operation. Put it on the floor and drop a steel ball into the "travel" tube. This will close the contacts and the vehicle will start roving over the floor. Test its reaction to the "stop" command first, and ensure that the impact of the falling ball is sufficient to break the contacts and stop the motor. If everything is in order, start the motor again and dropping the balls guide the PRV about the room without touching it with hands. If your construction is not too heavy, and the motor (or two motors) "pull" adequately, transfer the tests outdoors.

You can make the body of cardboard and cut holes for the balls writing which command is sent through which hole.

At the front of the vehicle you can install a rod to stop the motor if the machine strikes an obstacle. Also, it is possible to provide for the vehicles to back away after encountering an obstacle.

Think of the way to achieve this. The key to the problem lies at the steering mechanism.

SOIL SAMPLES FROM ANOTHER PLANET. Soviet automatic spacecraft have visited the Moon to take soil samples. Hollow drills extracted core samples and sealed them in a capsule. They were rocketed back to Earth to be studied in laboratories.

On the Moon the soil can only be dry, solid or loose. But on the planets where there is an atmosphere and water you can encounter any type of soil. Accordingly, soil samplers for materials with different physical properties must also differ.

Suppose you were commissioned to develop a device to sample a hard, but drillable soil on Mars or Venus. We will construct a model of such a device.

What must it look like?

Well, the most suitable solution seems to be the Archimedean

screw. You are already well acquainted with this screw because when you dismantle a mechanical meat mincer you will find a massive helical shaft – an Archimedean screw. The purpose of the screw is to feed meat to the cutter.

The Archimedean screw is widely employed to convey loose and paste-type materials. There are even pumps using this principle to deliver water.

Our model will also be based on the Archimedean screw, only it will work under no load conditions. Our micromotor is not hefty enough for our model sampler to take real samples, if only of sand.

To begin with, find a body for our device: a transparent plastic tube 2-3 centimetres in diameter. This will allow us to observe the rotation of the screw. Into one end of the tube insert a wooden stopper with a hole in the centre. Make a hole in the tube near the stopper to discharge the soil recovered into a hopper.

Now we will make the screw. Find a thin wooden rod 4-5 millimetres in diameter (perhaps an old paint-brush) and a rubber tube
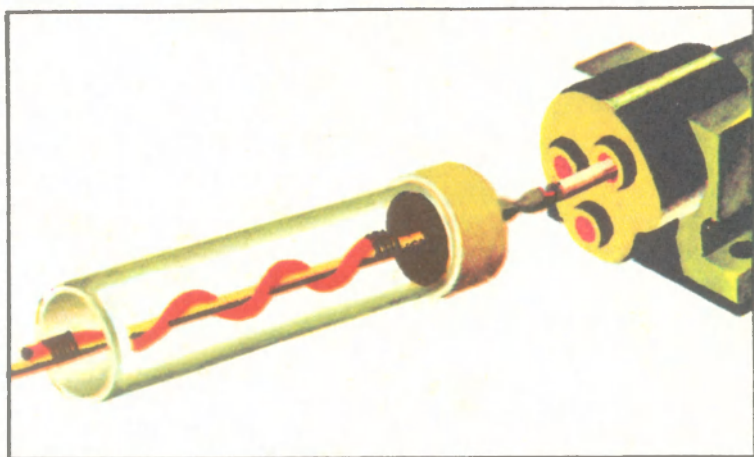
with an outer diameter of 5-6 millimetres. The rod must be about
5 centimetres longer than the body. Sharpen one end of the rod
and securely tie near its end an obliquely cut end of the rubber
tube. Bind the connection tightly with a string to obtain a smooth
transition from the end of the rod to the tube surface. Now, wind
the tube onto the rod up to about 3-4 centimetres before its other
end. The turns should be widely spaced as you wind them on and
not too tight in order that the tube does not deform. Fix the
second end of the tube by winding it tightly to the rod.

You have thus produced an Archimedean screw. Admittedly, it is
not normally made this way. A real screw is a flat metal belt wound
on a shaft so that it is perpendicular to the latter. But we have re-
placed it by a rubber tube. Insert the shaft-screw into the plastic
body, passing the blunt end of the rod through the hole in the
stopper and connect the micromotor to it.

The shaft end should protrude by 2 centimetres. Onto it fit
a piece of the rubber tube used for the spiral onto it. Using an
adapter (a piece of rod with ends of different thicknesses), attach
the nipple tube fitted onto the motor gear axle. This flexible con-
nection makes it possible to place the motor at an angle to the
screw axis.

Fix the body on a support or a bracket and connect the dry cell
to the motor. The screw will begin to rotate. Note the direction of
its rotation. In sinking into an imaginary soil the screw must drive
it to the outlet near the stopper and discharge into the hopper.

Now you are in a position to develop the system to start and
stop the engine, or the system to turn the body with the screw in
the direction required. To this end, use the devices developed for
the model planetary vehicles.

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FANTASIES WITH A CAMERA. All the painters interested in cosmic subjects have to rely on their imagination. And only someone who has been in space himself, can paint it from memory, rather than from imagination. The Soviet cosmonaut Alexey Arkhipovich Leonov visited space several times and had the rare opportunity to observe stars, the Moon, the Sun and our Earth not only from a spaceship porthole, but also during his walks in space. A. A. Leonov is an amateur painter and has devoted his leisure to fine arts.

Designing
Cosmic
Fantasies

Space is now a popular theme with artists who paint pictures, make illustrations devoted to man's prodigies in space. Maybe you too have a desire to dream about space with a pen or a brush in your hand. Themes are legion: you may draw distant worlds, travels and adventures on mysterious planets.

But there is also another way of designing cosmic fantasies – with the help of a camera. And with some experience, your pictures of fantastic subjects will look as if made from life.

Using a camera each of you will become a script writer, director, decorator, and camera man simultaneously. But the task should not scare you – you are equal to it. The camera is crucial for the job, it should be able to take pictures at a small distance (additional lenses are of help).

You will need to do the following. If you want to create a piece of art you should begin with a scenario, i.e., make a summary of what you want to show.

Next break the scenario up into individual frames arranged in a certain sequence. After you have come to a conclusion as to what each frame is to show, on a sheet of paper draw 9×12 cm rectangles, number them and, according to your scenario, sketch schematically what you are going to photograph in each of them.

Suppose it will be the landing of a mission on a Saturn's moon.

The moons of this planet are small and devoid of an atmosphere.
The members of the expedition must have their space suits on; they
take soil samples and observe Saturn rising above the horizon. You
want to photograph this particular moment. First of all, make
a mock-up of the still and then photograph it.

If your pictures are to be in black-and-white, then you do not
have to care for the colours. What is important is that when ade-
quately lit, dark objects will appear distinctly against a light back-
ground, and light ones against a dark background. They should
match to the background. The composition of a still should be care-
fully worked, with the objects and figures of peoples arranged on
different planes.

MOCK-UPS OF SPACE SCENERIES. For convenience, make
a "site" that might be located, say, on a stool. For the "site", you
could use a box or maybe a small table turned upside down. The
legs may be useful for fixing pieces of scenery. Between the legs,
place a smooth board to serve as the site.
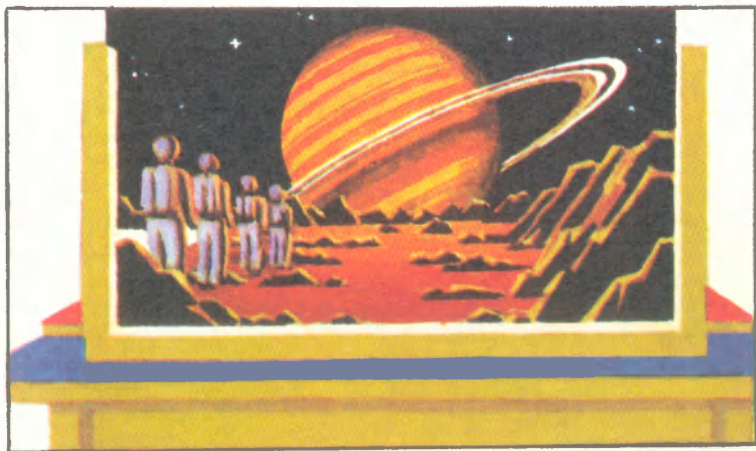
Make the background first. If it is to be starry sky, you can easily make it, even if you are a poor artist. Glue a piece of white paper to some cardboard, using rubber glue and dry it under a press. Next paint the paper black. You could of course, use black paper, but not a glossy one. Mix some whiting (gouache) with water in a saucer, and then dip a large brush (preferably made of bristle and used for oil painting) into the whiting. Having shed excess paint, begin to flick the whiting carefully onto the black paper by moving a knife or steel ruler over the end of the brush. It is a good idea to practice a bit first on a separate piece of black paper. The drops form an array of stars on the paper. Some of the drops are larger, others are smaller which produces an illusion of a star-filled sky.

Now that you have your skies, glue on a cardboard another paper and paint with water-colours Saturn with its rings. Allow the picture to dry and then cut the picture of Saturn out carefully and place it into your sky. Fix the planet lightly so that you could remove or shift it later. The surface of the Saturn's moon can be made of clay, stones, crushed bricks and sand. To make the scene look like real rocks, gorges and disrupted ground requires some imagination.

If some stills include a spaceship, then it should not be streamlined as on Earth. To start from a moon devoid of an atmosphere (due to its tiny size) the ship need not have any streamlining. Make this ship using various small objects of a regular form, a parabolic antenna to communicate with the Earth made of wire should be included.

Astronauts could be made of Plasticine. When everything has been made and arranged, light the mock-up carefully. See to it that the starry sky has no 'hotspots', and no shadows are cast by the rocks or people onto the background.

Now take a test picture. Use the test picture to eliminate drawbacks in order not to make them later. The final picture may look remarkably natural, as if taken not from a small mock-up, but from life.

In 1956, a Soviet popular science magazine published a "bird's eye" view of the lunar landscape. At the time no spacecraft had visited the Moon and the readers were clever enough to understand that this was not the Moon, but it occurred to nobody that the "lunar surface" was made of flour.

You could also create a slide film to be shown with a primitive projector. The film is produced on a slide film. The stills can sometimes be alternated with white lettering against a black background. The captions must be brief.

If a still requires close-ups of people, choose an "actor" from amongst your acquaintances and take his picture. You could then use photomontage. The required background is photographed separately using a conventional film, the people are then photographed in the appropriate stances and suits. (The size can then be adjusted at the printing stage.) You can draw something on the print, if necessary. Then cut the figures out and glue them to the photograph of the background, and retake the whole photograph. If you are making slides, you can photograph the frame directly onto the film, having once determined the sequence of stills. Photomontage is widely used by poster designers with good results.

By creating such slide films, or at least picture albums, you will be making the first steps to real creating activity as well as having very good time. It is not difficult to learn to photograph, and the manufacturing of scene-sets, costumes and other properties is not beyond your powers. Of course, such projects are better accomplished by a team. Through your imagination and the materialization of your ideas you sort of take part in a mission to distant worlds.

This completes our first acquaintance with self-made devices and vehicles. It is only the start on a long and exciting road to space. Good luck!
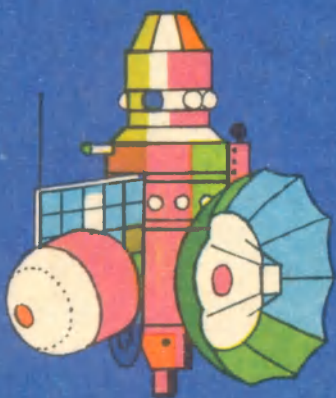
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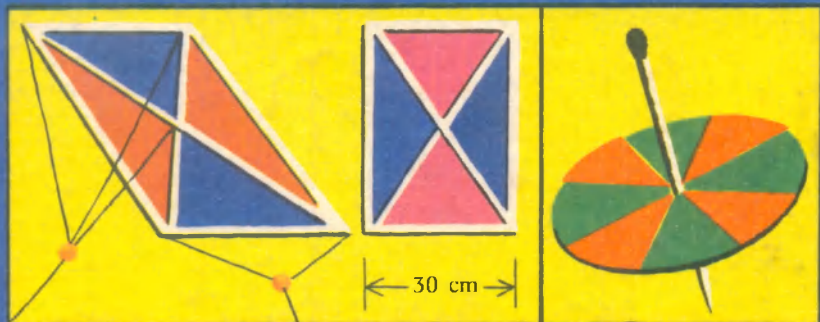
This book is not just good reading. It is meant to be read as a make-it book and a think-it book.
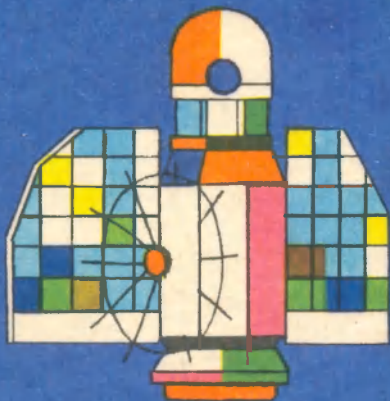
You will make simple models and devices to perform fascinating "space" experiments.

"Who knows, maybe these simple projects will eventually lead you to the ramp of a spaceship."

"Good luck, dear friends, and happy journey!"

Lunar probe "Zond 3" that photographed the Moon's surface

Interplanetary station "Venera 1"